A COURSE OF ELEMENTARY
PRACTICAL PHYSICS

PART II
HEAT AND LIGHT

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PREFACE

The following Course of Elementary Practical Physics combines the two current systems of Science teaching. The older method, by means of lectures, sometimes accompanied by a more or less detached series of practical experiments, is generally unsuitable for the younger pupils, and it has been condemned as not cultivating the spirit of intelligent inquiry. The newer or heuristic method has also been severely criticized, not on account of its unsuitability to the requirements of the pupils, but possibly owing to the zeal or, in some cases, to the lack of skill on the part of its exponents, and certainly to the fact that its results have not come up to expectation. Both systems have their good points, which the author has endeavoured to preserve in his attempt to combine them.

The Course, which has been in use for several years at King Edward VII School, Sheffield, is divided into two parts: (I) Mensuration, Mechanics, and Hydrostatics; (II) Heat and Light. In the former, the pupil is led to follow certain instructions and to obtain definite results; at the same time he is required to produce evidence that he understands and can express clearly his methods of working and the significance of the results obtained. The danger of too exclusive attention being given to the practical work is a real one, and it is therefore most important that more should be paid to the constant questioning on the methods used, and to the discussion of the results obtained. This point is emphasized by the frequent insertion of questions, problems, and calculations at various stages of the Course. The instructions given to the pupil are sufficient to set him working, but not too copious to prevent him thinking about what he has to do. No attempt is made to supply him with any information that he may reasonably be expected to obtain for himself, and he is frequently assisted in the right direction by questions, to which he must find the answers, before proceeding further. This, the author considers, is a legitimate application of the heuristic method. The problems, &c., are meant to be suggestive, and it is only by their correct appreciation

that the success of the work is assured. The oral discussion of them, previous to their being answered on paper, will be found useful, more especially to the class of pupil to whom a problem is frequently an excuse for not attempting anything.

There is a fairly general tendency among junior pupils to make notes of their experiments on scraps of paper or in stray books; and their solutions to problems, which in many cases are more essential to the correct understanding of their work than the experiment itself, obtain an equally casual existence. The author has avoided this tendency to slovenliness by allowing spaces wherein the pupil can record his experiments and solutions; it is intended that the pupil should enter his practical observations in the book as he makes them in the laboratory; but the questions should be first answered—say for Home Work or during Preparation—in an exercise-book, and then neatly transferred to the note-book after correction. By adopting this course, the pupil will have a permanent record of his practical work, and an invaluable summary of the applications of the scientific principles involved.

Where the experimental work necessitates expensive or complicated apparatus, or where a given result may be more quickly or more accurately obtained, the author has not hesitated to introduce the older lecture method, sparingly at first, but more widely in the later stages of the work, thus preparing the pupil for the time when this will be the chief source of his information. Occasionally the same point is illustrated by the more cumbersome experiment of the pupil and the neater demonstration of the teacher, and this lends an additional interest to the work, as most pupils appreciate a good experiment. The apparatus required for the Course is generally quite simple and inexpensive, and the quantity may be reduced by dividing up the class among two or more experiments, e.g. ordinary calipers may be used by one half of the class whilst the other half are using slide calipers, and again in the determination of the coefficient of expansion of a substance, one-third of the class may determine that of the solid, which requires somewhat expensive apparatus, whilst the other two-thirds determine those of the liquid and gas. The Course has been drawn up in such a way that this can frequently be done. It is also designed to avoid another difficulty—that of keeping the class together, without wasting the time of the quicker pupils or accepting bad work from the slower ones. The experiments have been arranged so that, whilst the latter are performing the necessary minimum, the former may be kept occupied with experiments of greater difficulty, the omission of which will not affect the progress and

continuity of the teaching. Hence at the beginning of a new section of the work the class may make a fresh start together.

The Course is a comprehensive one, and the teacher will be able to make a selection from it. The methods adopted are, as a rule, perfectly general, and in other cases the teacher is quite free to use his own. The earlier experiments are necessarily of a quantitative nature, but as soon as possible those of a qualitative character have been introduced. The tendency of elementary Science teaching, which at first was entirely of a qualitative nature, is now too much in the other direction, and boys are apt to lose interest in it. In conclusion, it must not be forgotten that the oral instruction of the teacher is of the greatest importance to pupils of the age at which this work is done; and this is where an elaborate text-book, with its many illustrations and diagrams, and its copious instructions and explanations, defeats his object and is a waste of material and time. At the same time, he must have some written scheme of work to put before the class if he is to make the best use of his time.

H. V. S. S.

SHEFFIELD, June 1912.

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HEAT

CHAPTER I

INTRODUCTORY

§ 1. Hot and Cold

Exp. 1. Holding a thermometer by the stem, place the bulb against various objects in the laboratory and note the position of the mercury thread in the stem.

Now touch these objects with your hand and note the difference.

Ques. 1. How do you account for it

2. Is the thermometer sensitive enough? If you think not, perform the following experiments with it: (*a*) breathe on the bulb; (*b*) place your hand round the bulb.

Ques. 1. Which of the above objects is the hottest? Which feels the hottest?

2. How do you account for the differences when using the hand?

Exp. 2.* Prepare three troughs of water containing: (1) hot water, (2) cold water, (3) lukewarm water. Place the right hand in the hot water for a minute and then in the lukewarm water.

Next, place the right hand in the cold water for a minute and then in the lukewarm water.

Now place the right hand in the hot and the left in the cold water for a minute, and then place them both in the lukewarm water.

Experiments marked with an asterisk may be performed by the teacher.

Ques. 1. What do we mean when we talk about a 'hot' or 'cold' day ?

2. Why is the hand not a good measurer of hotness or coldness ?

3. Under what circumstances do we use the hand as a measurer of hotness ? Is this always safe ?

§ 2. Heat and Hotness

Exp. 1.* Connect two pieces of glass tubing of different bores by rubber tubing and place a clip over the rubber.

(*a*) Pour water into each tube to the same height, open the clip, and note the result.

(*b*) Repeat the experiment after closing the clip and pouring more water into the left-hand tube.

(*c*) Repeat the experiment after closing the clip and pouring more water into the right-hand tube.

Express the results in a table, thus :

Which tube contains the greater amount of water ?	
" " " " height	
In which direction does the water flow ?	

What causes the flow of the water?

Make a diagram to illustrate this experiment.

Exp. 2. Mix together: (*a*) two equal quantities of cold water; (*b*) equal quantities of boiling and cold water; (*c*) a large quantity of cold water and a small quantity of boiling water.

Find the hotness of each before mixing and the hotness of the mixture.

Determine (1) which quantity loses heat, (2) which gains heat, (3) in which way the heat flows.

Make diagrams to show the flow of heat in each case.

Ques. 1. Which contains more heat: a red-hot nail or a bath of hot water?

2. Which is the hotter? In which direction will the heat flow if the nail is placed in the bath?

3. What word is used to denote 'hotness'? Does a very hot body contain much heat? Can a cold body contain any heat?

4. What is the name of the instrument used to measure the hotness of a body?

§ 3. Sources of Heat

Exp. 1. Hold a piece of magnesium in a pair of tongs in the flame of a Bunsen burner.

Exp. 2. Pour some water over a piece of quicklime in a dish.

Exp. 3. Carefully pour some water over a few drops of sulphuric acid, placed in a perfectly dry test-tube.

Exp. 4. Rub a metal button against the bench for about two minutes.

Exp. 5. Take the temperature of some cold water in a beaker and then stir it vigorously for a few minutes. Take the temperature again.

Exp. 6. Hammer a piece of lead for a short time.

[**Lecture.** 'THE SOURCES OF HEAT.']

Ques. 1. How is the heat obtained in the following cases: (*a*) a burning candle; (*b*) the brake of a wheel; (*c*) a bullet striking a target; (*d*) a bicycle pump when pumping up the tyre; (*e*) in a coal mine; (*f*) a hot spring; (*g*) a greenhouse.

2. Why does the barrel of a gun become very hot after several shots have been fired? How can this be prevented?

3. Why are the fragments of metal, which are bored or punched out of a piece of steel, so hot?

4. Describe the use of a flint and steel, and state what scientific fact is illustrated by it.

5. How is it explained that a small piece of iron hammered on the anvil becomes very hot ?

§ 4. Effects of Heat

Exp. 1. Place some cold water in a beaker and heat it with a small flame. Stir the water gently with a thermometer and take the temperature at intervals of one minute. Tabulate and plot the results.

Ques. 1. How many degrees does the water rise in : (*a*) one, (*b*) three, (*c*) five minutes ?

2. Is there any limit to the rise ?

3. What takes place when it is reached ?

4. Does the water rise 5 times as many degrees in 5 minutes as it rises in 1 minute (i.e. is the rise proportional to the time) ?

5. How do you account for this ?

Exp. 2. Try the effect of heating the following bodies : wax : lead sulphur ; ferric oxide ; mercuric oxide.

Exp. 3. Stretch a long wire horizontally between two stands and hang a weight from the centre. Fix a scale vertically at the centre of the wire and note the position of the wire. Heat the wire with a burner.

Ques. 1. What are the chief effects of heat on a body ?

What happens when a solid or a liquid is heated ?

CHAPTER II

EXPANSION

§ 1. Expansion of a Solid

Exp. 1. You are provided with an iron rod (the upright of a retort stand), a knitting needle, a strip of cardboard, and a tripod stand. Arrange these to show that the rod expands when heated. Sketch the apparatus.

Exp. 2.* Sketch the apparatus known as the 'bar and gauge', and describe how it is used to show that a solid expands in area when heated.

Exp. 3.* Sketch the apparatus known as Gravesande's 'ring and ball', and describe how it is used to show that a solid expands in volume when heated. How would you prove this with a metal sphere and a pair of calipers ?

Exp. 4. Fix two pieces of copper and iron wire with their ends in two binding screws and arranged so as to lie close together. Heat the two wires equally. Note and explain the result.

Ques. 1. Two strips of brass and steel are riveted together. What will happen when the combination is heated : (*a*) with the brass nearer the flame ; (*b*) with the steel nearer the flame ; (*c*) equally on each side ? Give reasons for your answer.

2. What alteration takes place in the length of: (*a*) railway lines; (*b*) signal wires: (*c*) steel girders. How may it be prevented?

3. What use can be made of the fact of expansion in the following cases: (*a*) the loosening of a glass stopper; (*b*) the making of a cart-wheel; (*c*) the manufacture of cannon?

§ 2. Expansion of a Liquid

Exp. 1. Fit a large flask with a cork and upright narrow tube. Fill it with water and press in the cork. Take care to leave no air in the flask. (How is this done?) Mark the level of the water in the tube and heat the flask for a few seconds.

Now heat the flask for some time and then allow it to cool.

Explain all the results.

Exp. 2. You are provided with two small flasks of nearly equal volume and a piece of narrow glass tubing. Devise and perform an experiment to find out whether all liquids expand the same amount when heated equally. Sketch the apparatus. What precautions must you take with regard to: *(a)* the quantity of each liquid; *(b)* the number of degrees you heat them? Compare the expansions by means of a graph.

Exp. 3.* Lantern Experiment to compare the expansions of different liquids.

Exp. 4. Carefully weigh in a counterpoised beaker 100 cc. of water at the following temperatures :—20°, 40°, 60°, 80°. Calculate the density of water at these temperatures. Plot the results. Is your result quite correct? Give a reason for your answer.

Ques. 1. A pint of cold water is mixed with a pint of hot water; will both pints together be a quart?

2. At what temperature will a pint of water have (*a*) the greatest, (*b*) the least weight?

3. Which is the heavier—a pint of hot water or a pint of cold water? How would you prove the truth of your answer without using a balance?

§ 3. Expansion of a Gas

Exp. 1. Fit a small dry flask with a cork and upright glass tube. Fix the flask so that the tube dips vertically into a beaker of coloured water. Fix to the tube a strip of cardboard with a cm. scale on it. Describe what happens when: (*a*) the hand is placed on the flask; (*b*) the hand is removed; (*c*) cold water is poured over it.

Ques. 1. For what purpose could you use this apparatus?

2. Is it sensitive ?

3. How would you increase the sensitiveness ?

4. What causes the water to rise up the tube ?

5. What must be done to lift up water ?

6. What can heat be turned into ?

7. How can work be turned into heat ?

8. How would you construct a simple apparatus to force water to a great height by means of expansion due to heat ?

9. What differences do you notice between the expansion of a solid, a liquid, and a gas ?

Exp. 2.* Set up an apparatus like the one used in the last experiment, but with a very large flask. Read the levels of the water in the tube on different days and compare them with the readings of a thermometer standing near to the apparatus. Do the readings agree ? Give reasons for your answer.

§ 4. Cooling by Expansion

Exp. 1.* Turn on the tap of an oxygen cylinder and allow the gas to escape for a short time. Note the effect on the nozzle at which the gas escapes.

Exp. 2.* Blow some air from a pair of bellows or bicycle pump on to the bulb of your air thermometer. Note and account for the effect produced. Hold your hand near the nozzle and note the effect.

Ques. 1. In order to make a gas expand, what must be done to it ?

2. If a gas expand, what must it take up ?

3. Whence does the gas obtain it ?

4. What happens to the temperature of the gas ?

5. Why does fanning produce a sense of coolness ?

6. How is it that a thermometer, placed under the receiver of an air-pump always falls as soon as the pump is worked ?

CHAPTER III

THERMOMETRY

§ 1. Construction of a Thermometer

Exp. 1. You are provided with a piece of narrow glass tubing with a bulb at one end and a funnel at the other, and with some coloured alcohol. Make an alcohol thermometer.

Exp. 2.* Having filled the bulb and stem with alcohol, the instrument must now be hermetically sealed. How and why is this done ?

Ques. 1. Can you make a scale on the thermometer with a foot rule or a cm. scale ?

2. If you wish to make any kind of scale, with what must you start ?

3. If you have no unit, in what other way must you proceed ?

4. Do you know any temperatures which are fixed ?

§ 2. Fixed Points of a Thermometer

Exp. 1. Break up some ice into small pieces and place a thermometer in them. Note the result.

Warm the ice gently and again note the result.

Try the experiment out of doors

Ques. 1. Does the temperature of melting ice vary ?

Exp. 2. Add a little salt to the ice and note the result.

Ques. 1. Can you be certain that the temperature at which ice melts never varies ?

Exp. 3. Fit a large flask with a cork, through which pass a thermometer and a bent glass tube. Place some water in the flask and boil it. Note the temperature at which the water boils : (*a*) when the thermometer bulb is in the water; (*b*) when it is above the surface : (*c*) when it is just below the cork. Repeat the experiment after adding : (*a*) sand : (*b*) salt to the water. Tabulate the results :

	In liquid.	*Above surface.*	*Near cork.*
Water			
„ + sand			
„ + salt			

Make a sketch of the apparatus.

Ques. 1. Does water always boil at the same temperature ?

2. What causes the differences noted above ?

Exp. 4.* To find out the effect of pressure on the boiling-point of water (*a*) the effect of increased pressure ; (*b*) the effect of diminished pressure.

Exp. 5. (*a*) Determine the fixed points of the given thermometer, or (*b*) correct the fixed points of the given thermometer.

Ques. 1. Why does a liquid not run down a narrow glass tube ?

2. What liquids are used for filling a thermometer ? State any advantages or disadvantages possessed by them.

3. Why must no air be left inside a thermometer ?

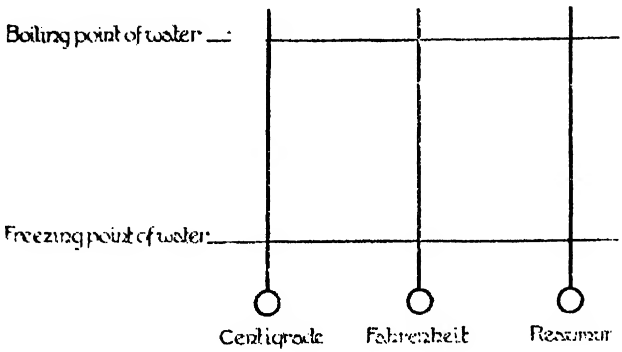
4. Give some common examples of substances which are hermetically sealed and give the reason for so treating them.

5. What would be the effect of : (*a*) increasing the size of the bulb (*b*) decreasing the width of the stem of a thermometer ?

§ 3. Thermometric Scales

Exp. 1. Place a Centigrade and a Fahrenheit thermometer, fixed together with rubber rings, in a beaker of water. Read the thermometers. Heat the water through 10° (about) and read again. Repeat until six readings of each thermometer have been obtained. Tabulate the results (see below, Ques. 7).

Ques. 1. Make a diagram to show the relation between the three thermometric scales, thus :



2. Make a graph to convert ° C. into ° F. and vice versa, given :

$$0^\circ \text{ C.} = 32^\circ \text{ F. and } 100^\circ \text{ C.} = 212^\circ \text{ F.}$$

3. Convert the readings obtained in Exp. 1 by means of the graph. Tabulate the results below (Ques. 7).

4. Convert 45° C. into ° F. thus :

$$\frac{45}{1} \times \frac{9}{5} = 81. \qquad 81 + 32 = 113^\circ \text{ F. Ans.}$$

5. Convert 77° F. into ° C.

$$77 - 32 = 45. \qquad \frac{45}{1} \times \frac{5}{9} = 25^\circ \text{ C. Ans.}$$

6. Convert the readings obtained in Exp. 1 in this way.

7. Tabulate the results obtained above, thus :

°F.	°F. by graph.	°F. by calculation.

8. Express the following important temperatures in ° C. or ° F. :

	° C.	° F.
The Sun	5700	
The Electric Arc	3500	
Bessemer Furnace		2741
Mercury boils at		675
Alcohol boils at		174
The Human Body	36·8	
The Sea (mean)		62·6
Mercury freezes at		−38·2

9. What temperature is expressed by the same number on each scale ?

10. Of two thermometers, one has its freezing-point and boiling-point marked on the top of Mont Blanc, the other at the bottom of a deep mine. In what respects will the fixed points of each of these thermometers differ from those marked on a standard thermometer ?

11. In the process of graduating a thermometer, the boiling-point is fixed whilst the instrument is immersed in steam and not in boiling water. Why is this ?

12. Why is a small thermometer better than a large one for scientific purposes ? Mention some of the disadvantages of small thermometers compared with larger ones.

13. Thermometers are usually filled either with mercury or alcohol. For what special purpose would you prefer one or the other ?

§ 4. Kinds of Thermometers

Exp. 1. Examine carefully the maximum thermometer provided. Breathe on the bulb and then allow it to cool. How would you set the thermometer again ? Give a careful description of the instrument, stating clearly : (*a*) its purpose ; (*b*) its construction ; (*c*) how it works ; (*d*) how it is read ; (*e*) how it is set.

Exp. 2. Describe in a similar way a minimum thermometer.

Ques. 1. What kind of thermometer would you use for finding the temperature of: (*a*) an oven; (*b*) a pond covered with ice; (*c*) a vessel containing lumps of ice? Give reasons for your answer.

2. Describe and sketch a clinical thermometer.

3. Describe and sketch a thermometer which will act as a combined maximum and minimum thermometer.

CHAPTER IV

EXPANSION (*continued*)

§ 1. Measurement of the Expansion of a Gas

Exp. 1. Fit a large round-bottom flask with a perforated rubber stopper, through which is passed a short glass tube attached to a piece of rubber tubing fitted with a clip. Sink it in a beaker of boiling water for five minutes and then close the clip. Then open it with the tube under cold water, and cool the flask to the temperature of the water. Note this temperature. Make the levels of the water inside and outside the flask equal and close the clip. Measure the volume of the flask and the volume of the water drawn in. Enter the results thus :

Volume of flask :

Volume of water drawn in. (Expansion) :

Temperature of boiling water :

Temperature of cold water :

Number of degrees the air has cooled :

Ques. 1. What volume of air has contracted ?

2. To what volume has it contracted ?

3. What is the contraction ?

4. What volume has expanded ?

5. What is the expansion ?

State clearly what you have determined, viz.

cc. of air, heated through °C., expand cc.

and then find what

1 cc. of air, heated through 1° C., expands cc.

This is called the coefficient of expansion of air (between the given temperatures).

§ 2. Measurement of the Expansion of a Liquid

Exp. 1. Given a specific gravity bottle and a liquid, devise and carry out an experiment to find out the coefficient of expansion of the liquid. State clearly what you intend to do before starting.

Enter the results thus :

Mass of bottle and liquid at °C. =

,, ,, =

,, liquid at °C. =

,, bottle and liquid at °C. =

,, ,, =

,, liquid at °C =

,, liquid, which has escaped =

Number of degrees heated =

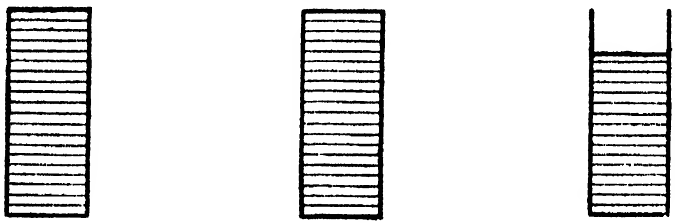
Therefore g. of liquid, heated °C., expand

Coefficient of apparent expansion of =

Ques. How would you calculate the coefficient of *real* expansion of the liquid ?

N.B. The following drawings illustrate the method of working out the result.

Bottle at 10° *C.* *Bottle at* 60° *C.* *Bottle cooled to* 10° *C. again.*



Volume = V	Volume = V	Volume = V'
Mass = M	Mass = M'	Mass = M'

Since the mass of a liquid is proportional to its volume
∴ since a mass M' has expanded a mass $M-M'$
∴ a volume V' ,, ,, volume $V-V'$

§ 3. Measurement of the Expansion of a Solid

Exp. 1. Examine and sketch the screw gauge provided. Set the instrument so that the distance between the jaws is : (*a*) 1 mm. ; (*b*) 3 mm. ; (*c*) 5 mm. ; (*d*) 2·5 mm. ; (*e*) 3·75 mm. ; (*f*) 4·83 mm.

Through what distance have they moved between the readings (*d*) and (*e*) ?

Measure the thickness of a cover-slip and a piece of zinc-foil.

Exp. 2. Fill a tin can with water and boil it. Make the length of the metal tube between the point at which it is fixed and the end which presses against the screw gauge exactly 1 metre. Press the screw gauge lightly against the end of the tube and take the reading. Repeat several times and take the average. Screw back the gauge (why ?) and pass steam rapidly through the tube until no further expansion takes place (how do you find this out ?). Then press the screw gauge against the tube and take fresh readings.

Describe and sketch the apparatus.

Enter the results thus :

Length of rod at °C. =

Reading of screw gauge at °C. =

,, ,, at °C. =

Expansion for °C. =

Therefore cm. of , heated °C., expand mm. = cm.

Coefficient of Linear Expansion of =

§ 4. Coefficients of Expansion

Solids.		*Liquids.*		*Gases.*	
Zinc	·000029	Water	·00019	Air and other gases	·00367 or 1/273
Brass	·000019	Mercury	·00018		
Copper	·000017	Alcohol	·00108		
Steel	·000012	Glycerin	·00018		
Iron	·000011	Paraffin	·00099		
Platinum	·0000089				
Glass	·000009				
Wood	·000005				
Invar	·0000009				

Ques. 1. Why can a platinum wire be fused into a glass rod ? What would happen with a copper wire ?

2. Show that : (*a*) the areal expansion of a solid is double (*b*) the cubical expansion of a solid is three times its linear expansion.

3. A pendulum is constructed of a long brass rod and a heavy brass bob. What variations would you notice in its time of vibration in winter and in summer ?

4. A flask fitted with a cork and upright glass tube is filled with cold water so that the latter stands some distance up the tube. What happens when the flask is placed in ice-cold water ? Give reasons for your answer.

5. What substance possesses a very small coefficient of expansion ? What use can be made of it ?

6. Describe and sketch (*a*) the gridiron ; (*b*) the mercurial pendulums

7. A pendulum is constructed of brass and steel rods. If the length of the former is three feet, how long must the latter be ?

8. How is a watch prevented from gaining or losing with change of temperature ? Give a sketch.

9. How would you construct a long metal rod so that its length would not vary at all with the temperature ?

10. A steel bridge is 325 ft. long. What variation in length would there be if the highest temperature in summer is 40° C. and the lowest temperature in winter is −20° C. ?

Range of temperature = 40—(—20) = 60.

∴ Variation = ·000011 × 60 × 325 = ·2145 ft.

= 2·57″ Ans.

11. A brass pipe through which steam is passing is 15 yd. long. What will its length be when filled with ice-cold water ?

For 1 yd. the expansion = ·000019 × 100 = ·0019 yd.

1 yd. of brass expands to 1·0019 yd.

? ,, ,, ,, 15 yd.

12. The length of an iron rod at 0° C. is 100 cm. Find its length at 50° C.

13. A lump of iron has a volume of 5 cu. ft. at 0° C. : find its volume at 80° C.

14. The density of lead at 0° C. is 11·4 g. per cc. Find its density at 200° C. (Coeff. of exp. = ·000029.)

15. A bottle weighs 50 g. when empty, and 710 g. when full of mercury at 0°C. On heating to 100° C., 10 g. of mercury are expelled. Find the coefficient of expansion of mercury.

16. In the above question, if the coefficient of real expansion is ·000181, find the coefficient of expansion of glass.

§ 5. Density of Water at Different Temperatures

Exp. 1.* Place the float provided in a beaker of cold water and gradually heat the water.

Exp. 2.* Fill the lead coil provided with water and place a cork and glass tube in the open end. Press the cork in so that the water stands nearly at the top of the glass tube. Place the apparatus in melting ice.

Exp. 3.* Sketch the apparatus for showing the point of maximum density of water. Describe the experiment carefully.

Exp. 4.* Sketch Hope's Apparatus and describe how it may be used to find the point of maximum density of water.

Ques. 1. Make a graph to show the changes of volume which water undergoes when it is cooled from 10° C. to 0° C.

2. Make a graph to show the changes water undergoes when it is heated from 0° C. to 100° C. How would you indicate the changes of density ? Data (after Rossetti) :

Temp.	*Volume.*	*Temp.*	*Volume.*	*Temp.*	*Volume.*	*Temp.*	*Volume.*
0° C.	1·000129	4° C.	1·000000	8° C.	1·[illegible]4	40° C.	1·0077
1	1·000072	5	1·000010		1·000176	60	1·017
	1·000031	6	1·000030	10	1·000253	80	1·029
	1·000009	7	1·000067	20	1·0017	100	1·043

3. Why does ice form at the top of a pond in winter ?

4. What is the temperature of maximum density of a liquid ? What would be the consequences if water had its maximum density at 0° C. ?

5. On a cold winter day when the temperature of the air is 10° C. below zero, a hole is made in the ice of a deep pond and the temperature is observed at various depths. What kind of a thermometer would you propose as most suitable for the purpose ? What variations would you expect to find ? Give reasons for your answers.

6. By what experiments or observations would you prove that cold water is heavier, bulk for bulk, than warmer water? Is this always the case? If not, state the exception, and describe some proof of the statement.

7. A piece of oak which floats in ice-cold water so as to be just immersed in it is taken out and placed into hot water. Will it sink now or rise above the level of the hot water, or will there be no difference?

CHAPTER V

HEAT CAPACITY

§ 1. Comparison of Heat Capacities

Exp. 1.* You are provided with three glass cylinders of different capacities. Place each in turn under a running tap for the same interval of time (say 10 seconds) and measure the height of water in each.

Ques. 1. What difference do you notice between them ?

2. Does each receive the same amount of water ?

3. Does each get filled to the same height ?

4. Why do the heights vary ?

5. Which has the greatest capacity ?

Exp. 2. Heat, in turn, 100, 200, 300 g. of water in a beaker with a small flame for equal times (say 2 minutes).

Ques. 1. What differences do you notice ?

2. Does each receive the same amount of heat ?

3. Does each get equally hot ?

4. Why do the temperatures vary ?

5. Which has the greatest capacity ?

Exp. 3. Determine by a suitable experiment which has the greater capacity for heat: water, alcohol, paraffin, turpentine, &c. Describe the experiment.

Exp. 4. Compare the heat capacities of any two of the following bodies copper, tin, zinc, lead.

§ 2. The Unit of Heat

Exp. 1. Find the temperature obtained by mixing: (*a*) 100 g. of water at 60° C. with 100 g. of water at 15° C.; (*b*) 100 g. of water at 60° C. with 200 g. of water at 15° C.

How are you to get rid of the error due to the vessel taking up heat?

Enter the results thus:

(*a*) 100 g. of water at ° C.	Temp. of	° C.	Fall. ° C.
(*b*) .. .. at ° C.	Mixture.		Rise. ° C.

The same amount of heat is required to raise

100 g. of water ° C. as is given out by 100 g. falling ° C.
1 g. .. 1° C. .. ,, ..

HEAT CAPACITY

Ques. 1. What is meant by the 'unit of heat'

2. How much heat is given out by the hot water in Exp. 1? Is this equal to the heat taken up by the cold water?

3. Calculate the amount of heat taken up by: (*a*) the water; (*b*) the alcohol, in § 1, Exp. 3. How much heat is required to raise the temperature of 1 g. of alcohol 1° C.?

4. Find the number of heat units required to raise: (*a*) 1 kg. of ice-cold water to the boiling-point; (*b*) 250 g. of water at 12° C. to 84° C.; (*c*) 100 g. of alcohol from 20° C. to 65° C.; (*d*) 1 kg. of alcohol from −10° C. to 50° C.

Table showing the Number of Heat Units required to raise 1 g. of a substance 1° C.

Alcohol	·620	Glass	·200	Copper	·095
Turpentine	·426	Sulphur	·180	Brass	·094
Mercury	·033	Iron	·114	Tin	·055
Aluminium	·214	Zinc	·096	Lead	·031

Definition. The Thermal Capacity of a body is the number of heat units required to raise that body 1° C.

Ques. 1. Find the thermal capacities of the following: (*a*) 1 litre of alcohol (density 0·78 g. per cc.); (*b*) 1 kg. of mercury; (*c*) a pint of water; (*d*) a lead bullet weighing 120 g.; (*e*) a stick of sulphur weighing 40 g.

2. Find the relation between the heat capacities of 1 g. of alcohol and 1 g. of water.

3. Find the relation between the number of heat units required to raise 120 g. of lead through 80° C., and the number required to raise the same mass of water through the same number of degrees.

4. If 1,000 heat units are required to raise a certain amount of water through a given number of degrees, how many will be required to raise the same amount of: (*a*) copper; (*b*) iron, through the same number of degrees?

5. You are given 1 lb. of iron and 1 lb. of lead. Describe fully some experiment by which you can show that, when both pieces of metal are heated from 0° C. to 100° C., the iron requires nearly four times as much heat as the lead.

6. Two vessels containing 100 cc. of water and alcohol respectively are heated to 50° C. After standing a short time, a thermometer is placed in each. What difference will be noticed? Explain your observation.

CHAPTER VI

CALORIMETRY

§ 1. Specific Heat and its Determination

Definition.—The Specific Heat of a substance is the ratio between the number of heat units required to raise any mass of the substance through any number of degrees and the number required to raise the same mass of water through the same number of degrees.

$$\text{Sp. Heat of substance} = \frac{\text{Heat required to raise 1 g. of subst. } 1^\circ}{\text{Heat required to raise 1 g. of water } 1^\circ}$$

The specific heat of a substance may be determined by:

(1) The Method of Mixtures: By mixing known masses of the substance and water at known temperatures and finding the temperature of the mixture.

(2) The Method of Cooling: By comparing the rates at which equal volumes of the substance and water cool.

§ 2. The Method of Mixtures

Exp. 1. Weigh out 200 g. of lead shot, place them in the heater with a thermometer and close the opening with a plug of cotton wool. Boil the water in the heater. Measure out 50 g. of cold water and place it in the inner vessel of the calorimeter. Place the latter inside the outer one, resting on a cork and prevented from touching it by means of a layer of cotton wool. As soon as the temperature of the heater has become steady, note it and remove the thermometer. Take the temperature of the cold water. Pour the lead quickly but carefully into the water, stir, and take the highest reading of the thermometer.

Enter the results thus:

g. of lead at °C.	Final temp.	°C.	Fall. °C.
g. of water at °C.			Rise. °C.

Heat given out by water =

Therefore g. of lead falling °C. give out heat units.

Ques. 1. What rise of the cold water was obtained above ?

2. What error are you likely to make in reading a thermometer ?

3. What per cent. error would there be if you made an error of 0·25° ?

4. Are you justified in measuring the water instead of weighing it ?

5. What are the chief sources of error in the above experiment ?

6. How can you make them as small as possible ?

Exp. 2. Weigh the calorimeter used in the last experiment and calculate its heat capacity (or water equivalent).

Find the water equivalent of the calorimeter by experiment. Describe the experiment.

Enter the results thus :

g. of water	°C.	Final temp.	°C.	Fall.	°C.
g. of water	°C.			Rise.	°C.

Heat given out by hot water	heat units
Heat taken up by cold water	,,
Heat taken up by calorimeter	,,
,, ,, ,, per degree	,,
Water equivalent of the calorimeter	,,

Compare this with the calculated result.

Exp. 3. Determine the specific heat of one of the following substances : copper (nails), iron (nails), zinc (granulated), tin (granulated), glass (beads). Describe the experiment carefully and make a sketch of the apparatus.

N.B. In case any of the substance should remain in the heater, it will be better to weigh the substance after it has been placed in the calorimeter. Hence proceed as follows : (1) Place a convenient quantity of the substance in the heater and boil the water ; (2) weigh the calorimeter (why ?) ; place a convenient quantity of water in it and weigh again ; (3) proceed as before and mix the substance with the water ; (4) weigh the calorimeter and its contents again (why ?).

Enter the results thus :

Mass of calorimeter, water, and substance.

substance.

Mass of calorimeter and water.

water.

Exp. 4. Find the specific heat of one of the following liquids: alcohol, turpentine, paraffin. Indicate the methods for all the liquids.

N.B. Before beginning the experiment, povr a little of the liquid into some water and see if any heat is given out. The method you adopt will depend on this.

§ 3. The Method of Cooling

Exp. 1. Compare the rate of cooling of a given volume of water when placed in: (1) a vessel with the outside brightly polished; (2) a vessel with the outside blackened. What difference do you notice? Plot the results on squared paper.

Repeat the experiment with an equal volume of some other liquid.

Compare the times taken by each liquid to cool 10°. Find the density of the liquid and calculate the mass used, or weigh it.

Enter the results thus:

Mass of Liquid. Time taken to cool 10°.

Mass of water.

Heat given out by water.

" " liquid.

What is the ratio between these two amounts of heat, and for what reason? Calculate the specific heat of the liquid.

Ques. 1. Calculate the specific heats of the following substances from the following data:

	(*a*)	(*b*)
Mass of substance	100 g.	30 lb.
Temperature of substance . . .	98·5° C.	100° C.
Mass of water	9 g.	60 lb.
Temperature of water	10·3° C.	13·2° C.
Final temperature	19·2° C.	17·8° C.

2. What temperature is obtained by mixing together:

(*a*) 10 g. of water at 100° C. with 50 g. of water at 15° C.

(*b*) 20 g. „ 80° C. „ 100 g. „ 12° C.

3. What temperature is obtained by mixing together :

(*a*) 250 g. of tin at 99° C. with 50 g. of water at 15·5° C.

(*b*) 1 g. of boiling water with 19 lb. of iron at 18° C.

4. Calculate the specific heats of the following substances from the following data :

	(*a*)	(*b*)
Mass of substance in g.	166	21
Temperature of substance in ° C. . .	99·5	98
Mass of water in g.	49	100
Temperature of water in ° C. . .	12	10
Final temperature in ° C. . .	14·5	11
Water equivalent of calorimeter . .	2·1	3·6

5. 105 g. of copper are heated to 98·5° C., and mixed with 90 g. of water at 10·3° C. in a copper calorimeter weighing 25 g. The temperature after mixing is found to be 19° C.; what is the specific heat of copper?

6. Find the specific heat of alcohol from the following data:

Mass of copper calorimeter	20·4 g.
,, ,, ,, and alcohol . .	70·5 g.
,, ,, ,, , alcohol and copper	81 g.
Temperature of alcohol	10° C.
,, ,, copper	98° C.
Final temperature	12·6° C.
Specific heat of copper	0·095

7. A platinum ball weighing 200 g. is placed in a furnace for a short time and then plunged quickly into a vessel containing 150 g. of water at 13° C., whereby the temperature is raised to 30° C. Find the temperature of the furnace (sp. ht. of platinum = 0·031).

8. Equal volumes of alcohol and water were cooled in a vessel. The times of cooling from 60° C. to 55° C. were 140 seconds for the alcohol and 280 seconds for the water. Find the specific heat of alcohol (R. D. = 0·8).

9. In the determination of the specific heat of a liquid by the method of cooling, the weight of the copper calorimeter was 162·6 g., its weight with the liquid was 271·8 g. and with the water 301·4 g. The times of cooling from 50° to 45° were 140 seconds for the liquid and 330 seconds for the water. Find the specific heat of the liquid.

10. How is the climate of the British Isles affected by the high heat capacity of water?

11. On entering the sea on a summer morning the water feels cold, but in the evening it feels warm. Explain this.

12. Why is water used for filling hot-water bottles and foot-warmers?

13. What causes the difference between continental and island climates?

CHAPTER VII

FUSION AND SOLIDIFICATION

§ 1. Melting Points

Exp. 1. Place some shavings of wax in a dish and melt them with a small flame. Allow the wax to solidify and melt it again. Take the temperature of the melted wax and also the temperature at which it solidifies. Repeat the experiment several times.

Exp. 2. Dip the bulb of the thermometer into some melted wax. Watch the bulb, and as soon as the wax solidifies read the temperature. Repeat several times and take the average.

Exp. 3. Melt some wax in a metal vessel and place a thermometer in it. Allow the wax to cool, and take the temperature at regular intervals. Plot the results on squared paper. What does the graph teach you ?

Exp. 4. Draw out a piece of glass tubing into a capillary tube. Suck up a little melted wax into it and fasten it to a thermometer. Place the latter in a beaker of water and heat it with a small flame. Note the temperature at which the wax melts. Allow the water to cool and note the temperature at which the wax solidifies. Stir the water all the time, and repeat the experiment until the two temperatures are very close together.

Exp. 5. Find the melting-point of: (*a*) butter; (*b*) sulphur.

Ques. 1. A piece of ice and a lump of sealing-wax are placed in separate vessels and heated. What difference do you notice in their behaviour?

2. What substances behave like sealing-wax when they are melted?

§ 2. Change of Volume on Fusion

Exp. 1. Fit a flask with a cork and a narrow upright tube. Fill the flask with ice-cold water and put some lumps of ice into it. Mark the level of the water in the tube. Allow the ice to melt and note the result.

Exp. 2.* Fill the metal vessel provided with ice-cold water and screw in the plug. Place it in a freezing mixture and note the result.

Exp. 3. Melt some wax in a metal vessel and add pieces of wax until it quite full of just melted wax. Allow the wax to solidify and note the result.

Ques. 1. How do you account for the leaking of water pipes after a severe frost? How can you prevent the pipes from being burst?

2. Explain why the ice of a pond, which has just frozen, is sometimes found to be overhanging the edges.

3. What substances expand on solidifying? What advantage is taken of this?

4. One afternoon in winter, when the temperature is about 7° F. below the freezing-point of water, a hollow steel shell is filled with water and closed by a stout plug. What will happen if the temperature now rises, and what if it falls?

§ 3. Latent Heat of Fusion

Exp. 1. Put a large lump of ice in a metal vessel, placed inside a larger vessel containing boiling water. Stir, and note the time taken to melt the ice and the time taken by the water to rise about 30° C.

Enter the results thus :

Time taken to melt the ice

Time taken by water to rise

Heat required to melt the ice =

Heat required to melt 1 g. of ice =

Exp. 2. Determine the temperature obtained by adding several large pieces of dry ice to a quantity of warm water. Arrange the conditions of the experiment so that no heat shall be lost or gained by the calorimeter.

Ques. 1. How are you going to weigh the ice ?

2. Why must you use a few large pieces and not a number of smaller ones ?

3. How will you dry the ice ?

4. If the air is at 15° C. and the warm water at 25° C., to what temperature would you cool it ?

Enter the results thus :

g. of ice at	° C.	Final temp.	° C.	Rise	° C.
g. of water at	C.			Fall	C.

Heat given out by the water . . . . . . =

Heat required to raise the water from 0° C. to C. =

Difference = heat required to melt the ice . . =

Mass of ice melted . . . . =

Heat required to melt 1 g. of ice, i.e. to change 1 g. of ice at 0° C. into water at the same temperature . =

N.B. Before weighing the calorimeter for the last time, look at the outside. What do you notice and what will you have to do ?

5. Find the latent heat of fusion of ice from the following data: mass of water, 129·1 g.; temperature of water, 18° C.; mass of ice, 22·15 g.; final temperature, 4·5° C.

6. Find the latent heat of fusion of ice from the following data

Mass of brass calorimeter	35 g.
,, ,, ,, and water . .	156 g.
,, ,, ,, water and ice . .	165 g.
Temperature of water	24° C.
Final temperature	17° C.
Specific heat of brass	0·09

7. What will be the temperature obtained by mixing: (*a*) 1 lb. of snow with 4 lb. of water at 60° C.; (*b*) 300 g. of melting ice with 700 g. of boiling water; (*c*) 500 g. of alcohol at 50° C. with 50 g. of melting ice.

e. g. Heat taken up by melting ice	=
Heat given out by water sinking to 0° C. . . .	=
Balance = heat to raise the water	=
Mass of water at 0° C.	=
Number of degrees the latter is raised	=

8. Find the specific heat of the following substances from the given data :

	(*a*) Mercury	(*b*) Iron
Mass of substance in g. . . .	6800	1000
Temperature of substance in ° C. .	56°	100°
Mass of ice melted . . .	159	143

9. If the specific heat of tin is 0·055, and its latent heat of fusion is 14·25, what quantity of heat is required to raise 10 lb. of tin from 100° C. to its melting-point, 240° C. ?

10. Describe Regnault's Ice Calorimeter and explain how to use it.

11. Each of two similar vessels contains 1 lb. of water at 0° C.; but, whilst the water in one vessel is all liquid, one-half of that in the other is in the solid state. If 1 lb. of water at 100° C. be poured into each of the two vessels, why is the temperature in them different? What will it be in either?

§ 4. Heat of Solution

Exp. 1. Find the temperature obtained by adding the following bodies to water: salt, saltpetre, ammonium nitrate, caustic soda.

Find the exact alteration of temperature.

Exp. 2. Find the temperature obtained by mixing together: (*a*) salt and ice; (*b*) calcium chloride and ice.

Exp. 3.* Place a mixture of salt and ice in a metal vessel, and stand it in a plate of water for a short time.

Exp. 4. Melt some crystals of 'hypo' in a flask. Allow to cool with a thermometer placed in the liquid. Read the thermometer at regular intervals, but do not stir the liquid.

Ques. 1. Of two vessels, one contains a little alcohol and the other a little water, both at the same temperature. Into each liquid a piece of sugar is dropped. It is found, after a few minutes, that the sugar is dissolved in the water but not in the alcohol, whilst a delicate thermometer held in each liquid shows that they are no longer at the same temperature. Which is the colder, and why ?

2. A solution of salt is carefully cooled down to a temperature of $-5°$ C. On stirring the liquid, solidification sets in and the temperature rises to $-1°$ C. Explain this.

3. Give reasons why a low temperature is obtained by mixing the following bodies together: (*a*) ice and nitre; (*b*) ammonium nitrate and water.

§ 5. **Lecture** 'On Regelation'

CHAPTER VIII

VAPORIZATION AND BOILING

§ 1. The Boiling-Point of a Liquid

Exp. 1. Place some water in a distilling flask, fitted with a cork and thermometer. Immerse the bulb in the water and heat.

Exp. 2. Find the boiling-point of: (*a*) alcohol; (*b*) aniline. How will you prevent the loss of the liquid? Give a sketch.

Exp. 3. Fix up and sketch an apparatus for finding the effect of pressure on the boiling-point of water. Do not use a pressure greater than 10 cm. of mercury.

Exp. 4. Show, by means of a simple experiment, the effect of diminished pressure on the boiling-point of water.

Ques. 1. What do you mean by the boiling-point of a liquid ?

2. Describe carefully all you notice when a large beaker of cold water is heated by means of a burner.

3. The boiling-point of water falls about 1° C for every 1,080 ft. above sea-level. What will be the boiling-point at Quito (9,500 ft. above sea-level)?

4. Describe the hypsometer and state what it is used for.

5. Describe Papin's digester, or an autoclave, and state what it is used for.

§ 2. The Latent Heat of Steam

Exp. 1. Pass some steam into 100 g. of cold water until the temperature rises 20° or 30° C. Note the rise and the mass of steam used. Repeat the experiment, using the same mass of boiling water.

Ques. 1. What difference do you notice?

2. How do you account for it?

Exp. 2. Find as accurately as you can the temperature obtained by mixing dry steam with cold water. In this way determine the latent heat of steam.

Ques. 1. How are you to obtain dry steam?

2. How are you going to weigh the steam?

3. How much steam must you pass in ?

Describe the experiment carefully and make a sketch of the apparatus used.

Enter the results thus :

Mass of calorimeter, water and steam

" " and water.

" "

" steam.

" water.

Temperature of steam

water.

Final temperature.

Water equivalent of calorimeter.

g. of steam at	° C.	Final temp.	° C.	Fall	° C
g. of water at	° C.			Rise	° C

Number of heat units taken up by water.

" " given out by water from the steam.

Difference = heat given out by the steam condensing.

Heat given out by 1 g. of steam at ° C turning into water at the same temperature = latent heat of steam =

Ques. 1. Observations and experiments show that neither the freezing-point nor the boiling-point is always the same. State the various circumstances which lower or raise either, and explain how these circumstances are taken into account when the fixed points are marked on a thermometer.

2. Name the three states of matter and the cause to which changes from one state to another are chiefly due.

3. Determine the latent heat of steam from the following data: mass of steam, 5 g.; mass of water, 120 g.; temperature of water, 10° C.; final temperature, 35° C.

4. What temperature is obtained by mixing: (*a*) 5 g. of steam with 995 g. of water at 20° C.; (*b*) 5 g. of steam with 100 g. of melting ice; (*c*) 2 lb. of steam with 500 lb. of alcohol at 15° C.

e.g. (*a*)

How much heat is given out by the steam in condensing?

„ „ „ water formed?

What is the total amount of heat given out?

How much heat does the water require to raise it 1° C.

To what temperature will it be raised ?

5. What is the result of mixing : (*a*) 1 lb. of steam with 8 lb. of melting ice ; (*b*) 1 lb. of steam with 1 lb. of ice ?

e. g. (*a*)

Total heat given out by the steam and water,

Number of g. of ice melted.

6. Make a graph to show the change of volume which occurs when a piece of ice at $-20°$ C. is heated.

Data :

Temp.	*Volume*	*Temp.*	*Volume*	*Temp.*	*Volume*	*Temp.*	*Volume*
$-20°$	1·0900	0° (water)	1·0001	50°	1·0120	100° (steam)	1650
0° (ice)	1·0908	4°	1·0000	100°	1·0432	110°	1690

.. What difference would it make to the fish in a river if the specific and the latent heats of water were only small ?

8. In what respects does water differ remarkably from other liquids ?

§ 3. Evaporation and Vapour Pressure

Exp. 1.* Devise experiments to find out the effect of : (*a*) temperature (*b*) pressure ; (*c*) extent of surface ; and (*d*) a current of air on the rate at which water or alcohol evaporates.

Exp. 2. Compare the rates of evaporation of the following liquids: water, alcohol, carbon disulphide, ether.

Exp. 3.* Set up a barometer and mark the height of the mercury in the tube. Pass up the tube a drop of water on a piece of filter paper. What happens?

Pass up other drops until no further change takes place. Measure the alteration in height of the mercury column and note the temperature. Repeat the experiment, using alcohol or ether instead of water.

Exp. 4.* Enclose the barometer containing the water and the water vapour in a wider glass tube, and pass steam through it.

Ques. How would you define the boiling-point of a liquid ?

Exp. 5. Sketch the apparatus for finding the correct boiling-point of a liquid and use it to find the boiling-point of one of the liquids given in Exp. 1.

Ques. 1. Some water is heated in a shallow vessel, provided with a loosely fitting cover. Describe what takes place inside the vessel. What difference would it make if the cover were removed ?

2. Three small thin glass tubes are half filled, one with sulphuric acid, another with water, and a third with ether. They are sealed up and placed in a vessel of boiling oil. What will happen in each case ? Give reasons for your answer.

3. A saucer containing water is placed on a window-sill. What circumstances will favour the rapid disappearance of the water ?

4. Two vessels, one containing water and the other ether, are alike in all respects. What difference would you notice if a thermometer were placed in turn in each vessel ?

5. Make a graph to show the maximum vapour pressure of water between 0° and 100° C.

Temp.	*Press.*	*Temp.*	*Press.*	*Temp.*	*Press.*	*Temp.*	*Press.*	*Temp.*	*Press.*
0°	4·6	6°	7·0	12°	10·4	18°	15·3	60°	148·9
1°	4·9	7°	7·5	13°	11·1	19°	16·3	70°	233·3
2°	5·3	8°	8·0	14°	11·9	20°	17·4	80°	354·9
3°	5·7	9°	8·5	15°	12·7	30°	31·5	90°	525·5
4°	6·1	10°	9·1	16°	13·5	40°	54·9	100°	760·0
5°	6·5	11°	9·8	17°	14·4	50°	92·0		

6. What is meant by a good drying day ? What atmospheric conditions are essential ?

7. What happens to the steam issuing from the funnel of an engine : (*a*) on a fine warm day ; (*b*) on a cold damp day ?

§ 4. Heat absorbed during Evaporation

Exp. 1. Wet a cloth and hang it up in a draught to dry; after a short time, measure its temperature.

Exp. 2.* Place a drop of water on a wood block and over it place a watch glass. Fill the latter with ether and make it evaporate quickly by blowing a current of air over it.

Exp. 3. Mix together some baking soda and strong hydrochloric acid, and measure the fall of temperature.

Exp. 4.* Describe, with a sketch, the experiment with Wollaston's cryophorus, and give reasons for the result.

Ques. 1. A thermometer has its bulb covered with a piece of muslin. If a few drops of the following liquids be placed in turn on the muslin, what would you notice: linseed oil, water, ether?

2. Why are roads and pavements watered in summer?

3. Describe a good method of cooling: (*a*) a room in summer; (*b*) a bottle of wine in hot weather without using ice.

4. Why should one always change after taking violent exercise?

5. Why does a dog hang out its tongue in hot weather?

CHAPTER IX

CONDENSATION AND HYGROMETRY

§ 1. Condensation

Exp. 1. Boil some water in a flask provided with a delivery tube and cork. Describe the appearance: (*a*) at the end of the tube; (*b*) at some distance from it; (*c*) at a considerable distance from it; (*d*) inside the flask above the water. Hold a beaker containing cold water near the end of the tube and note the result.

Ques. 1. Describe the appearance of steam, water vapour, mist, water. State exactly the form of the water in each case.

2. How can water vapour be condensed?

Exp. 2. Obtain a specimen of pure water from the sample provided.

Exp. 3. You are given a mixture of alcohol and water. Prepare a specimen of strong alcohol from it.

Exp. 4.* Place a flask containing some warm water under the air pump and work the pump for a few strokes. Note and explain the result.

Ques. 1. What becomes of the steam which escapes from a kettle of boiling water ?

2. What happens to air, saturated with water, if it is cooled ?

3. How is it that two liquids can sometimes be separated by distillation ?

4. How is it that the wind feels colder at the top of a cliff than at the bottom ?

5. Explain the formation of cloud, mist or fog, rain, snow, hail, dew, and hoar frost.

§ 2. WATER VAPOUR IN THE AIR

Exp. 1. Place some water in a beaker and allow it to stand for a short time. If nothing happens, add a few lumps of ice to the water.

Exp. 2. Weigh rapidly on a clock glass a small quantity of one of the following substances: caustic soda, calcium chloride, concentrated sulphuric acid. After exposing it to the air for a short time, weigh again.

Exp. 3.* Sketch the apparatus used to find the mass of water vapour in the air and describe the experiment.

Ques. 1. A quantity of air is placed in a tube, standing in a bath of mercury. How would you saturate this air with water vapour ?

What would happen if the air in the above question were : (*a*) heated ; (*b*) cooled ?

2. What would happen if you cooled a vessel containing air, which was damp but not saturated ?

3. The mass m (in grams) of moisture in a cubic metre of air saturated at various temperatures $t°$ was determined as in Exp. 3, and the following results were obtained :

t	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°
m	4·9	5·2	5·6	6·0	6·4	6·8	7·3	7·7	8·1	8·8	9·4	10·0
t	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°
m	10·6	11·3	12·0	12·8	13·6	14·5	15·1	16·2	17·2	18·3	19·3	20·4

Plot these results on the squared paper on which the relation between temperature and vapour pressure was plotted.

§ 3. Hygrometry

Exp. 1. Find the temperature at which the air deposits moisture in the form of dew. You are provided with a bright metal vessel, a thermometer, and some ice.

Ques. 1. How much moisture would the air contain if it were saturated at its ordinary temperature ?

2. How much moisture does the air actually contain ?

3. Find the relative humidity or dampness of the air, i.e. the ratio between the moisture actually contained in it and the moisture necessary to saturate it.

Exp. 2.* Describe and sketch the hygrometer provided, and explain how it is used to find the dew point.

Ques. 1. What are the essential parts of a hygrometer? Compare the merits of the hygrometers you know.

2. A person wearing spectacles comes into a warm room after a walk in the frosty air. What happens to his spectacles, and why?

3. How is dew formed? What conditions are favourable to a heavy fall of dew?

4. If, on a certain day, it was found that the dew point was: (*a*) very high; (*b*) very low; (*c*) equal to the temperature of the air, what would be the hygrometric state of the air in each case?

5. Four pegs are driven into the ground and the four corners of a blanket are fixed to them. Would you expect to find dew under or on the top of the blanket?

6. Find the relative humidity of the air if the temperature is 16° C. and the dew point is 10° C.

7. If the relative humidity of the air is 0·75, and its temperature is 15° C., find the dew point.

CHAPTER X

TRANSMISSION OF HEAT

§ 1. Conduction of Solids

Exp. 1. Place two of the given wires (of equal length and thickness) in a beaker of boiling water, so that one inch of each is immersed. Hold the other end between your finger and thumb.

Exp. 2. Hold the piece of sensitive paper provided near the burner, and note the result. Use the paper to show what happens when a metal rod is heated at one end. Note the appearance of the paper at short intervals and explain the results. Make a drawing to illustrate the state of the rod at various stages of the experiment.

Exp. 3. Compare the conducting powers of a thick and a thin rod of copper.

Exp. 4. Compare the conducting powers of two different metals.

Exp. 5.* Sketch : (*a*) Ingen-Hausz's apparatus ; (*b*) Edser's apparatus, and describe how they are used to determine the relative conductivities of substances.

Ques. 1. When a long copper rod is heated at one end, in what state is the rest of the rod ?

2. In what state will it be after a considerable interval ?

3. What determines the rate at which a body becomes hot ?

4. Place the following bodies in order of their conductivities :—lead, glass copper, bismuth, iron, wood.

5. Two very short cylinders of copper and bismuth are placed on an iron plate. On the top of each is placed a piece of wax, and the plate is heated at a point midway between the two cylinders. It is found that the wax melts on the bismuth first. Now copper is a better conductor of heat than bismuth. How do you explain the result? What would happen if the cylinders were much longer?

§ 2. Convection

Exp. 1. Nearly fill a tall beaker with water and place at the bottom a few pieces of magenta. Heat the water gently and note the result. Make a diagram to illustrate it.

Ques. 1. What change takes place in the temperature of the water ?

2. What does the water do in consequence of this ?

3. What change of density must the water undergo ?

4. What does the change of density bring about ?

5. How is the heat conveyed to the top of the water

6. In what direction does the heat pass, and why ?

7. Could heat pass in the opposite direction ?

8. Can water be made less dense by heating it ?

9. What experiment have you seen in which heat travels down ?

Exp. 2.* Describe the experiment which shows how a convection current is produced in a liquid.

Exp. 3.* Sketch the apparatus which illustrates the method of heating a building by hot water.

Exp. 4. Devise an experiment to show that convection occurs in a heated gas, e.g. the air over the burner.

Exp. 5. Place a lighted candle in a trough containing a little water. Put over it a narrow lamp-glass and note the result. Place a piece of cardboard in the top of the lamp-glass so as to divide it into two passages, and note the result. Devise a means of showing the existence of two convection currents.

Ques. 1. Why is the candle extinguished at first ?

2. Why does it continue to burn afterwards ?

3. Of what does the down current consist ?

4. Of what does the up current consist ?

5. How do you account for the formation of a draught ?

6. What are the causes of : (*a*) land and sea breezes ; (*b*) the Trade Winds ?

7. What are the causes of the currents in the ocean ? Give an example of such a current.

8. What are the chief objects of ventilation? How is this effected in the case of: (*a*) a living room; (*b*) a school room?

§ 3. Conduction of Liquids and Gase

Exp. 1. Devise an experiment to find out whether water is a good or a bad conductor of heat. You are provided with a strip of sensitive paper, a test-tube, and a copper wire.

Exp. 2. Compare the conductivities of mercury and one of the following liquids : alcohol, turpentine, water.

Exp. 3. Wrap a piece of wire round a lump of ice or wax and place it at the bottom of a test-tube nearly full of water. Heat the water near the top until it boils, and note the effect on the solid at the bottom.

Exp. 4. Compare the conductivities of : (*a*) a copper rod, and (*b*) a tube of the same internal thickness, filled with copper filings.

Exp. 5. Place some powdered chalk or sand on the palm of your hand and rest a red-hot wire on it. Note and explain the result.

Ques. 1. What difficulty is there in comparing the conductivities of liquids and gases? How is this difficulty avoided?

2. How is it that you can stir hot water with your hand whilst you cannot hold your hand still in it?

3. What difference would you notice if: (*a*) you kept your hand still in some cold water; (*b*) you moved your hand about in it?

Lecture · On Conduction

Ques. 1. Does clothing afford us heat in winter? How then does it keep us warm? Explain the term 'insolation'.

2. Why will the moistened finger or the tongue freeze instantly to a piece of iron on a cold winter day but not to a piece of wood?

3. Why can hot water be poured into a glass beaker but not into a glass jam-jar without cracking it?

4. Why is a cellar cool in summer and warm in winter?

5. How would you protect: (*a*) water pipes; (*b*) a football field, from frost?

6. How is heat conserved in boilers and steam-pipes; and cold in refrigerating chambers?

7. Which would be warmer—one thick blanket or two blankets of half the thickness of the former?

8. Describe and sketch a Thermos flask and explain the fact on which it depends for its usefulness.

§ 4. Radiation

Exp. 1. Place two thermometers, *A* and *B*, at distances of 6 and 8 inches respectively from a burner. Note the reading of each and then light the burner. After a short time, note the readings again.

Ques. 1. In what ways could the heat pass to the thermometers?

Exp. 1a. Shield one thermometer, *A*, from the burner by means of a sheet of cardboard, and note the effect.

Ques. 1. Can the heat still pass to the two thermometers in the same way?

2. Why is the reading of *A* lower than that of *B*?

3. Does the heat now pass to *B* and not to

4. Can this process be conduction or convection

5. In what other way can heat pass ?

Exp. 2.* Compare the radiating powers of various surfaces by means of either: (*a*) a strip of sensitive paper; (*b*) Crookes's radiometer; or (*c*) a thermo-pile and galvanometer. Sketch the apparatus in each case.

Exp. 3.* Compare the absorbing powers of various surfaces by means o a strip of sensitive paper coated with these surfaces.

Exp. 4.* Devise an experiment to show that radiation may be reflected by means of a polished surface.

Exp. 5. Devise an experiment to find if radiation will pass through glass.

Ques. 1. In what different ways do you receive heat when sitting in front of a fire ? Which is the most important ?

2. How would you prove experimentally that a good absorber of heat is also a good radiator ?

3. Which will be cooler on a hot day, a white hat or a black one

4. Which makes the better teapot : silver or earthenware ?

5. Why should fire-irons be brightly polished ?

6. Two kettles containing cold water are standing in front of a bright fire. One kettle is very black, but the other is brightly polished.

What difference will this make? Which kettle would boil the sooner if placed on the fire, and why?

7. Explain carefully how the laboratory is heated.

CHAPTER XI

THE LAWS OF GASES

§ 1. Boyle's Law

Exp. 1. Find the relation between the volume of a gas and its pressure. You are provided with two glass tubes, *A* and *B*. *A* is closed at one end. Connect the other end to the tube *B* by means of a piece of pressure tubing and clamp them to a stand. Pour mercury into the apparatus until it stands about half-way up each tube. Read the heights of: (*a*) the top of the tube *A*; (*b*) the mercury in *A*; (*c*) the mercury in *B*. Raise or lower the tube *B* and take fresh readings of (*b*) and (*c*). Repeat until several readings have been obtained. Make a sketch of the apparatus.

Enter the results thus :

Pressure of the Air   *cm.*

a	*b*	*c*	*Vol. of Air, a − b*	*Press. of mercury c − b*	*Total Press. in cm.*	*Vol. × Press.*

Plot the relation between the volume and the pressure.

Express this relation in words. It is known as Boyle's Law.

Ques. 1. The volume of a gas at 760 mm. pressure is 500 cc. What will the volume be at 750 mm. pressure ?

2. The volume of a gas at 700 mm. pressure is 1 litre. What will be the volume at 750, 800, 1,400, and 350 mm. pressure?

3. The volume of a gas at normal pressure (760 mm.) is 1,500 cc. What will the pressure be when the volume is 1,000 cc., 500 cc., 750 cc., 2,000 cc.?

4. The internal volume of an oxygen cylinder is 1 cu. ft. If the pressure of the gas in it is 120 atmospheres, how much gas would escape from it when the tap is opened?

§ 2. Charles's Law

Exp. 1. You are provided with a U-tube of narrow glass tubing, with one of its limbs closed. Fix it to a cm. scale and place a short column of mercury at the bend. Hang the apparatus in a tall beaker of water, provided with a long wire stirrer and a thermometer. Note the temperature and the position of the index. Heat the water about 10° C. higher and read again. Repeat until several readings have been obtained. Make a sketch of the apparatus and plot the results on squared paper.

Ques. 1. At what temperature would the volume of the gas be zero?

2. Deduce the coefficient of expansion from the graph.

3. The volume of a gas at 0° C. is 273 cc. What will be the volume at

1° C.	cc.	10° C.	cc.	200° C.	cc.	−50° C.	cc.
2° C.	cc.	20° C.	cc.	273° C.	cc.	−100° C.	cc.
3° C.	cc.	50° C.	cc.	−1° C.	cc.	−200° C.	cc.
5° C.	cc.	100° C.	cc.	−10° C.	cc.	−273° C.	cc.

4. Is the volume of a gas proportional to its temperature in ° C.?

5. What is meant by the Absolute scale of temperature?

6. What is the relation between the volume of a gas and its absolute temperature?

This is known as CHARLES'S LAW.

7. The volume of a gas at 0° C. is 819 cc.; what will the volume be at 10° C., 20° C., 25° C., 100° C.?

8. The volume of a gas at 10° C. is 566 cc. ; what will be the volume at 20°, 50° C., 5° C., 0° C. ?

9. Reduce to N.T.P. (normal temp. 0° C. and normal press. 760 mm.) : (*a*) 875 cc. at 15° C. and 745 mm. press. ; (*b*) 150 cc. at 17° C. and 770 mm. press.

10. At what temperature will the volume of a gas at 0° C. double its volume, the pressure being constant ?

§ 3. Coefficient of Increase of Pressure of a Gas

Exp. 1.* Describe and sketch the constant volume air thermometer, and show how it is used to determine the coefficient of increase of pressure of a gas.

LIGHT

CHAPTER I

RECTILINEAR PROPAGATION; PHOTOMETRY

§ 1. Rectilinear Propagation

Exp. 1. Make a pin hole at the centre of each of three squares of cardboard and place them at various distances from a bats-wing burner. Arrange them so that the holes are in a straight line. Look through them at the burner. Now move one of the screens a little and note the result.

Ques. What do you learn from this experiment

Exp. 2. Arrange at short distances from each other a burner, a screen with a pin hole in it, and a screen. Measure the heights of the flame and its image, and the distances of the flame and second screen from the pin-hole screen. Repeat the experiment with the screen at different distances. Enter the results thus:

Height of flame.	*Height of image.*	*Dist. of flame.*	*Dist. of image.*

Prove that these quantities are in proportion, and illustrate the experiment by means of a scale drawing.

Exp. 3. Fix a ruler vertically between the burner and a screen. Describe the shadows produced when the burner is placed : (*a*) edge on ; (*b*) broadside on to the flame. Make careful drawings to illustrate what you observe.

Exp. 4. Devise and carry out an experiment to find out the relation between the sizes of the object and shadow and their distances from the light.

Ques. 1. How would you mark out a straight line on a lawn without using a line?

2. Describe the pin-hole camera. What would be the effect of changing: (*a*) the shape of the hole; (*b*) increasing the size of it; (*c*) making several holes?

3. Describe with drawings : (*a*) an eclipse of the moon ; (*b*) an eclipse of the sun.

4. Find the size of a shadow cast by : (*a*) a 6 in. square block of wood 1 ft. in front of a flame, on a screen 30 in. from it ; (*b*) a wooden disc of 10 cm. radius, 25 cm. from a light, on a screen 1 m. away.

5. A dark room, 12 ft. square, with white walls, has a small hole in one wall. Sixty yards away, there is a tower 80 ft. high. How high will the image, formed inside the room, be? If the image of a tree 30 ft. high is 6″ high, how far away must it be?

6. What are the chief differences between a shadow and an image?

§ 2. The Law of Inverse Squares

Exp. 1. Make a square hole in a sheet of cardboard and fix it 1 ft. in front of a screen. Place a small candle flame 1 ft. in front of it. Measure the size of the bright patch of light on the screen. Place the screen 2 ft. away and measure again.

Compare the brightnesses of the two patches. Make a scale drawing to show their formation. The source of light must be taken as a point. Calculate the area of each patch and its relative illumination.

Ques. 1. Why do the calculated results not agree with the experimental ones ?

2. What would be the brightness of the patch, if the screen were at a distance of : (*a*) 3 ft. ; (*b*) 5 ft. ; (*c*) 10 ft. from the hole ?

3. What law can you deduce from the results ?

4. If the unit of brightness (or intensity of illumination) be the brightness of a screen placed at unit distance from a single candle, find the intensity of illumination of a screen placed at distances of : (*a*) 3, 6, and 10 ft. from a single candle ; (*b*) 10 ft. from a 10-candle power gas flame.

§ 3. Illuminating Power ; Photometry

Exp. 1. Find the distances at which 1 candle and 2 candles must be placed so as to give the same intensity of illumination on a thin paper screen. Place a screen between the two lights so that they do not interfere with each other. Repeat the experiment with 1 and 3 candles.

Enter the results thus :

1 candle at a dist. of in. = 2 candles at a dist. of in.

in. = 3

Deduce a law for comparing the illuminating powers of two lights.

Exp. 2. Compare the illuminating powers of your burner and a candle flame.

Exp. 3. Find the distances at which 1 candle and 2 candles must be placed so as to cast shadows of equal darkness. Repeat with 1 and 3 candles and deduce the law.

Exp. 4. Compare the illuminating powers of the burner and candle by this method.

Exp. 5. Make a grease spot on a sheet of unglazed paper. Place 2 candles 1 m. apart and move the paper about between them until the spot disappears. Measure the distances of the paper from the lights and deduce a law. Use it for comparing the illuminating powers of the burner and candle.

Ques. 1. What is meant by the candle power of a source of light ?

2. What is the candle power of your burner according to the various determinations you have made ? Why do the results not agree ?

3. What unit is generally adopted in photometry ?

4. What is a photometer ? Describe the various photometers you have used.

5. Define intensity of illumination and illuminating power.

6. Find the C.P. of : (*a*) a bats-wing burner, which when placed 3 ft. from a screen throws as deep a shadow as a standard candle 9″ away ; (*b*) an incandescent burner, which produces at a distance of 3 ft. 6″ as deep a shadow as a standard candle 6″ away ; (*c*) an arc lamp, which gives a shadow of the same intensity as a candle, at thirty times the distance.

7. A glow lamp of 36 C.P. is placed 1 ft. from a screen. At what distance would you place a burner of 16 C.P. so as to give the same brightness.

CHAPTER II

REFLECTION AT A PLANE SURFACE

§ 1. The Laws of Reflection

Exp. 1. Place the plane mirror provided on the line AB and pins at C and D on the same side of AB. Place a third pin in front of the mirror in a straight line with the images of the other two pins. (Call this point E.) Remove the mirror and pins. Join CD and produce it to meet AB at O. Join OE and draw ON perpendicular to AB. Measure the angles CON and EON. Repeat the experiment with the pins in other positions.

Ques. 1. What would you call :

CO.

NO.

EO.

Angle CON.

Angle EON.

2. What do you learn from this experiment ?

Exp. 2. Replace the pins at C and D as in Exp. 1. Arrange them so that their heads are at the same height. Place a pin at E so that its head coincides exactly with the images of the heads of the other two pins. Measure the heights of the pins.

What do you learn from this experiment ?

Exp. 3. Place a retort stand on the window-sill opposite to a vertical window bar. Standing several yards away, move your eye : (a) to the right ; (b) to the left. Note the apparent movement of the stand with respect to the window bar. Next, looking at some object outside the room, repeat the experiment and note the movement of this object with respect to the window bar.

Enter the results thus :

(1a) the stand appears to move to the , i.e. in the direction.

(1b) ,, ,, ,, , ,, ,,

(2a) ,, ,, ,, , ,, ,,

(2b) ,, ,, ,, , ,, ,,

Finally, place the stand close against the window bar and repeat.

Ques. 1. What rule can you deduce from the above results ?

2. Travelling in a train, a person sees a cow lying down several yards in front of a tree. What does he notice as he passes ?

3. A person, walking past a clock tower, notices the time just before and just after he passes. What curious difference might he observe ?

Exp. 4. Find the position of the image of a pin placed in front of a plane mirror. Compare the distances of the object and the image. Give a diagram.

Exp. 5. Place a pin in front of a plane mirror, and find the position of the image by placing several pairs of pins in front of the mirror in a line with it.

Ques. 1. Prove geometrically that the angle of incidence is equal to the angle of reflection, when the image is formed the same distance behind the mirror as the object is in front.

2. *ABC* is an angle drawn on a sheet of paper; how would you bisect it with the aid of a mirror and some pins?

3. State the laws of reflection of light.

Exp. 6. Prove experimentally that the reflected ray moves through twice the angle through which the mirror revolves.

Exp. 7. Write your name on a sheet of paper in thick letters and blot it at once. Hold the paper and blotting paper in front of a mirror and note the result.

Exp. 8. Place a silver coin with its edge on the bench and look at its image in the bench. Look at it again with your eye on a level with the bench.

Ques. 1. The reflected image of a small speck on the front of a mirror appears to be just one inch behind it. Explain, with the help of a diagram, how you can find the thickness of the glass.

2. The rays of the sun, reflected from a pool of water, are observed when the sun is high and again when the sun is low. What difference is noticed?

3. Make a drawing to find the image of an object AB, 3 cm. long, placed in front of a plane mirror; the distance of A from the mirror is 6 cm., and the inclination of AB to the mirror is 60°.

N.B. When making a graph to show the position of an image of an object placed in front of a mirror, note the following points:

(1) Draw two rays from each of the extreme points of the object. One of these should be a normal ray.

(2) Place arrow-heads on the ray to show its direction.

(3) All rays produced backwards behind the mirror should be drawn with dotted lines.

4. Make a drawing to show how the eye sees the image of a point in a plane mirror.

5. A man is 6 ft. tall; how tall must a mirror be for him to see his whole height in it.

§ 2. Multiple Images.

Exp. 1. Draw two parallel lines 3″ apart and place a plane mirror on each of them. Place a pin between them. Find the positions of the images formed and explain their formation by means of a drawing.

Measure the distances of the images from one of the mirrors.

What is the distance between the (1) 1st image in *A* and the 1st image in *B*, and (2) 2nd image in *A* and the 2nd image in *B*?

What is the distance between the alternate images formed by each mirror?

Exp. 2. Find the number and position of the images formed by two mirrors at (*a*) right angles; (*b*) 60°, 45°, or 30°.

Ques. 1. A ray of light falls on a mirror at an angle of 45°. Find the deviation produced.

2. At what angle must a mirror be placed to turn a beam of light through an angle of 90° ?

3. An object is placed 1″ from a mirror *A* and $1\frac{1}{4}$″ from a mirror *B*, at right angles to *A*. Find graphically the positions of the images formed.

4. A mirror, which is 2 ft. in front of an object, is moved back 1 ft. How far does the image move ?

5. Find the number of images formed by two mirrors, inclined at angles of 36°, 40°, and 72°.

CHAPTER III

REFRACTION AT A PLANE SURFACE

§ 1. The Laws of Refraction

Exp. 1. Place the rectangular block of glass on the paper and trace round its edges with a pencil. Place a pin close to the front edge of the block at *Q*, and another further off at *P*. Looking through the block at the pins, place a third pin, close up against the edge of the block at *R*, in a line with the images of *P* and *Q*. Then looking through the block at the pin at *R*, place a fourth pin at *S* on the far side of the block, so that *P*, *Q*, *R*, and *S* are all in the same straight line. Remove the block and pins and join *PQ*, *QR*, and *RS*. Note the change in the direction of the incident ray *PQ*, and show that it emerges from the block parallel to its original direction.

Exp. 2. Draw a circle of 5 cm. radius with centre O. Draw a diameter AOB and a diameter COD at right angles to it. Place the glass block with one edge along COD, and place a pin at O. Place pins along the circumference from A to C at E, F, G, &c. Looking through the block, place pins close up against the front edge of the block in a line with the images of the pin O and the pins E, F, G at E', F', and G' respectively. Remove the block and pins and join EO, OE', FO, OF', &c. Measure the angles of incidence and refraction.

Tabulate the results thus :

Angle of incidence (i)	*Angle of refraction* (r)	*Ratio of* i *to* r

Ques. 1. What inference can you draw from the resu

Next, draw EL, FM, &c., perpendicular to AO, and $E'L'$, $F'M'$ perpendicular to BO. Measure the lengths of these perpendiculars and tabulate the results thus :

Length of perp.	*Length of perp.*	*Ratio*

Or you may find the sines of the above angles and tabulate thus :

Sine of angle of incidence	*Sine of angle of refraction*	*Ratio of sin* i/ *sin.* r.

What inference do you draw from the results ?

Exp. 3. Devise an experiment to show that the incident ray, the normal, and the refracted ray are all in the same plane.

Exp. 4. Rule six parallel lines $\frac{1}{2}''$ apart and place the glass block across them. Rotate the block until a line, as seen through the block, appears to have moved through three spaces. Trace round the block with a pencil and then remove it. Draw the ray and obtain two values of μ from the drawing.

Exp. 5. Find the index of refraction for air and water by using a glass trough with thin sides.

Exp. 6. Find the position of the image of a pin placed close up against the edge of a glass block and looked at through the block by: (*a*) the parallax method; (*b*) the sighting method. Measure the distance (u) of the pin from the front edge of the block and the distance (v) of the image. Show that $\mu = u/v$.

Exp. 7. Repeat the above experiment, using water instead of glass.

Exp. 8. Find the apparent depth of a cylinder of water in the following ways: (*a*) Fix a small flame above the water, and adjust its height above the water until its reflected image in the water coincides with the image of some object placed at the bottom of the water; (*b*) Fix a circular disc of cardboard

round the cylinder and adjust it until it coincides with the image of the bottom. Obtain two values for μ from the results.

Ques. 1. A ray of light passes from one medium to another, making the angle of incidence 45° and the angle of refraction 30°; find the refractive index of the second medium.

2. In an experiment to find the refractive index of a substance, the following readings were taken :

Angle of incidence . .	30° 40′	40° 50′	60° 20′	70° 30′
Angle of refraction . .	19° 50′	25° 50′	35° 24′	38° 56′

Find the average value of the refractive index.

3. Explain, with the aid of a drawing, how a person sees a pebble at the bottom of a pond. If the observer is directly over the pebble and the pond is 3 ft. deep, how far will the pebble appear to be from him ?

4. Explain, with the aid of a drawing, how a fish sees the image of a tree on the bank of a river.

5. Explain why a straight stick, partly immersed in water in a slanting position, appears bent at the surface of the water.

6. Make a diagram to show the passage of a ray of light from glass to water. What is the index of refraction?

§ 2. Refraction through a Prism

Exp. 1. Place the given equilateral prism on paper and trace round it with a pencil. Place pins at A and B on one side of it, and, looking through the prism from the other side, place pins at C and D in a line with the images of A and B. Remove the prism and pins and join AB and CD. Produce AB and DC to cut the sides of the prism at E and G. Produce AC to F. Produce DG to cut AF at K. Measure the deviation, i.e. the angle DKF. Repeat the experiment, inclining the ray AF at different angles.

Exp. 2. Measure the refracting angle of the prism in the following ways: (*a*) Draw a long line on the paper and place a pin at one end of it. At the other end place the prism with its apex on the line. Looking into the prism, place a pin in a line with the reflected image of the first pin and the apex of the prism. Repeat this on the other side. Remove the prism and join the apex to the pins. The angle so formed will be twice the angle of the prism. Give a geometrical proof of this. (*b*) Place a pin in front of one side of the prism, and a second in a line with the first pin and its image. Repeat this on the other side, and so obtain a normal to each side. Produce these normals to cut each other and measure the angle between them

§ 3. Total Internal Reflection. The Critical Angle

Exp. 1. Place the given right-angled prism on paper and outline it with pencil. Draw a straight line at right angles to one of its sides (not the hypotenuse) and place two pins on it. Looking into the other side, place two pins in a line with the reflected images of the other two. Draw the incident and reflected rays and measure the angles of incidence and reflection. Note that the pins cannot be seen through the prism.

Exp. 2. Place the block of glass $ABCD$ on paper and outline it. By means of pins, trace a ray $PQRS$ through the block as in Exp. 1, § 1. Now move the block sideways, but still keeping its longer sides AB and CD on the original lines, until the pins P and Q can no longer be seen in the direction SR. By looking into the block their images may be seen, reflected in the side BC (or AD). Place two pins in a line with these images and call them T and U. Remove the block and join UT. Trace the ray $PQVTU$ (V is the point at which the ray suffers total internal reflection). Measure the angles of incidence and reflection.

Exp. 3. Place a right-angled prism on a piece of squared paper with one side at right angles to the lines. Look through the hypotenuse and note the appearance of the lines, and then revolve the prism and note the result. Determine roughly the angle at which the change takes place.

Exp. 4. Make a drawing to show the course of rays, proceeding from a luminous point under: (*a*) water, (*b*) glass, and striking the surface at angles of 20°, 40°, and 60° with the normal.

Determine the angle of incidence for which the angle of emergence is 90°. What will happen to a ray striking the surface at this angle?

Determine this 'critical' angle experimentally by using a hemispherical block of glass.

Exp. 5. Place a coin at the bottom of a beaker of water. Place your eye in such a position that you: (*a*) can see the coin through the surface of the water; (*b*) cannot see it in this way: (*c*) can see the image of it reflected in the surface of the water. Make sketches and give an explanation.

Exp. 6. Hold an empty test-tube in a beaker of water. Note and account for its appearance, when viewed in certain positions.

Exp. 7.* Hold a lighted candle in front of a thick sheet of glass and note the images produced when viewed obliquely. Make a drawing to account for their formation.

Repeat the above experiment, using a mirror of thick glass.

Ques. 1. Make a drawing to show the course of rays through an equilateral prism, when the angles of incidence are 20° and 60°.

2. Make a drawing to show what a fish sees when in the water.

3. The bed of a river is covered with pebbles. Explain, with the aid of a sketch, how some of these are visible and some invisible to a person wading in the water.

4. Explain the formation of a mirage. Where are they formed, and what differences are there between them ?

5. What is the cause of atmospheric refraction? State some of its effects. Explain why a mixture of two transparent liquids is sometimes opaque.

6. Why is a piece of writing paper opaque, and how can it be made transparent?

7. A glass rod is immersed in a beaker of Canada balsam. How do you account for the fact that it is invisible?

8. A person, looking at a fish swimming in a tank at an aquarium, is surprised to see two. Explain this with the aid of a drawing.

CHAPTER IV

MIRRORS AND LENSES

§ 1. Position and Nature of the Images

Exp. 1. Place two pins in corks and fix the given concave lens in a stand. Place the lens in front of one of the pins and determine: (*a*) the nature of the image formed, i.e. whether erect or inverted, magnified or diminished; (*b*) the position of the image, i.e. whether in front of or behind the lens, nearer or farther from the lens than the object. Vary the distance of the object pin and tabulate the results thus:

Dist. of Object.	*Position of Image.*	*Erect or inverted.*	*Magnified or diminished.*	*Nearer or farther from the lens than the Object.*

Exp. 2. Repeat the experiment, using a convex lens. Enter your results as above.

Exp. 3. Repeat, using a concave mirror.

Exp. 4. Repeat, using a convex mirror.

Exp. 5. Examine the following pieces of glass, and state whether they are plane sheets of glass or lenses. If lenses, state the kind of lens.

§ 2. The Concave Mirror

Exp. 1. You are provided with a concave mirror and an optical bench, on which are placed a mirror or lens stand, an object screen, and an image screen. Describe it briefly and make a sketch of it.

There is a mark on each screen, which represents its centre. The distance between the mirror and one of the screens is not necessarily equal to the distance between the marks on them, so that it is necessary to obtain a correction, known as the 'index error', for each screen and stand used. Cut off a piece of glass tubing exactly 20 cm. long, and arrange the mirror on its stand so that it is exactly 20 cm. from the object screen. Find the distance between the marks on the two stands. Suppose this to be 20·6 cm. Then the true distance between the mirror and the object screen will always be ·6 cm. less than the distance between the marks. The index error for this combination is said to be − ·6 cm., and it must be added to the distance between the marks to give the true distance between the mirror and the screen.

Determine the index errors of the object and image screens when used with the stand holding the concave mirror.

Exp. 2. Set up the object screen in front of the mirror and illuminate it with the burner. Move the image screen about until a clear image is formed on it. The mirror will have to be slightly tilted. Measure the distance between each screen and the mirror by means of the marks on them, and correct for the index error. Repeat the experiment with the object screen at various distances, and enter the results thus :

Dist. of Object $= u$.	*Dist. of Image* $= v$.	*Reciprocal of* $u = U$.	*Reciprocal of* $v = V$.	$F = U + V$.	*Focal length* $f = 1/F$.

Plot the results on squared paper, taking the values of u as abscissae and the values of v as ordinates. Find the value of the focal length from the graph.

Exp. 3. Move the object screen about in front of the mirror until a clear image is formed on it. Find the distance of the screen from the mirror, and compare it with the value of the focal length found above.

Exp. 4. Examine the spherometer provided ; describe and sketch it.

Place the spherometer on the piece of glass provided, and turn the head until the point of the screw just touches the glass. Read the scale round the head; if the reading is not zero, determine the error.

Measure the thickness of some cover slips, separately, and then all together.

Place the spherometer on the concave mirror used in the last experiment, and take the reading when the screw touches the surface of the mirror. Calculate the radius of curvature of the mirror, using the formula:

$$2R = d + r^2/d,$$

where R = the radius of curvature,

d = distance the end of the screw has moved,

r = distance between the end of the screw and one of the legs.

Compare this value with that obtained in the last experiment with the mirror.

Ques. 1. Make a drawing to represent a concave mirror with a radius of curvature 10 cm. Mark in it: (*a*) the centre of curvature; (*b*) the radius of curvature: (*c*) the focus: (*d*) the focal length; (*e*) the principal axis; (*f*) the pole.

2. Make a drawing to represent a concave mirror of 6 cm. focal length. Take a point (not on the principal axis) 15 cm. from the mirror, and draw from it: (*a*) a ray parallel to the principal axis; (*b*) a ray passing through the centre of curvature; (*c*) a ray passing through the focus; (*d*) a ray striking the mirror at the pole. Find the reflected ray in each case and the image of the point.

3. Make a graph to show the formation of the image, 4 cm. high, of an object, placed at distances of: (*a*) 20 cm.; (*b*) 8 cm.; (*c*) 3 cm. in front of a concave mirror of 5 cm. focal length.

4. Calculate the positions of the images in the above question, using the equation:

$$V + U = F \quad \text{or} \quad 1/v + 1/u = 1/f.$$

Exp. 5. Place a scale in front of the mirror, and find the position of the image by means of another scale so arranged that there is no parallax between them. Arrange the scales so that the image is half the size of the object. Measure the distances of object and image from the mirror. Repeat the

experiment, making the image double the size of the object. Enter the results thus :

Dist. of Object.	*Dist. of Image.*	*Ratio.*	*Dist. of Object from centre of curvature.*	*Dist. of Image from centre of curvature.*	*Ratio.*	*Magnification.*

Ques. 1. Prove geometrically that the magnification is proportional to : the distances of the object and image from the (1) mirror ; (2) centre of curvature.

2. Ca[illegible]e the sizes of the images formed in Ques. 3 (above), and compare the results with those obtained by the graphical method.

3. An object, 4″ high, is placed 25″ in front of a concave mirror of 10″ focal length. Find the position and size of the image.

4. An object, placed 50 cm. in front of a concave mirror, forms an image 10 cm. in front of the mirror. Find its focal length.

5. An object, 24″ in front of a concave mirror, forms an image three times its own size. Where is it formed, and what is the radius of curvature of the mirror?

6 Fill in the following table:

Position and Nature of the Images formed by a Concave Mirror.

Position of Object.	*Position of Image.*	*Nature of Image.*
Beyond r.		
At r.		
Between r and f.		
At f.		
Between f and the pole.		

Make a graph to show the relation between the positions of the object and image.

§ 3. The Convex Lens

Exp. 1. Find the position of the image formed by a convex lens, when the object is placed at various distances from it.

N.B. Distances measured in the opposite direction to that in which the light is travelling are to be regarded as positive; in the same direction as negative.

Obtain six pairs of values of u and v, and tabulate the results thus:

v.	u.	V.	U.	$V+U=F$	$f=1/F$

Exp. 2. Arrange a plane mirror, convex lens, and object screen, so as to obtain an image of the latter on the screen itself. Measure the distance of the lens from the screen, and compare it with the value of the focal length obtained in the last experiment.

Exp. 3. Find the position of the virtual image formed by a convex lens by using pins mounted in corks. Calculate the value of the focal length from the results.

Exp. 4. Focus the image of a distant object, such as a window, on a screen, using the convex lens. Measure the distance of the screen from the lens.

Ques. 1. What is meant by the focal length of a lens?

2. What is the relation between the distances of the object and image and the focal length?

3. Make a drawing to represent a convex lens of 10 cm. focal length. Take a point (not on the principal axis) 15 cm. from the lens, and draw from it: (*a*) a ray parallel to the principal axis; (*b*) a ray through the focus; (*c*) a ray through the centre of the lens. Trace the course of these rays through the lens, and find the image of the point.

4. Make a graph to show the formation of an image by a convex lens of 10 cm. focal length of an object, 4 cm. high, placed: (*a*) 25 cm.; (*b*) 5 cm. in front of the lens.

5. Calculate the positions of these images, using the formula

$$V - U = F \quad \text{or} \quad 1/v - 1/u = 1/f.$$

Exp. 5. Using a piece of wire gauze for an object, measure the magnification produced by the convex lens.

Enter the results thus :

v.	*u.*	*Ratio.*	*Magnification.*

Ques. 1. Prove geometrically that the magnification = v/u.

2. An object 3″ high is placed : (*a*) 18″ ; (*b*) 4″ in front of a convex lens of 6″ focal length. Find the position and size of the image formed.

3. An object placed 10 cm. in front of a convex lens gives an image five times its own size. Find the position of the image and the focal length of the lens.

4. Where must an object be placed in front of a convex lens of 8 cm. focal length so as to give an image : (*a*) 25 cm. in front ; (*b*) 25 cm. behind the lens

5. Fill in the following table:

Position of Object.	*Position of Image.*	*Nature of Image.*
Beyond the focus.		
At the focus.		
Between the focus and the lens.		

Exp. 6. Find the focal length of a combination of two convex lenses whose focal lengths are known.

Enter the results thus:

f_1	f_2	F_1	F_2	$F = F_1 + F_2$	$f = 1/F$	f (*found*)

§ 4. The Concave Lens

Exp. 1. Find the focal length of a concave lens by combining it with a stronger convex lens and finding the focal length of the combination.

Ques. 1. What difficulty do you meet with in dealing with a concave lens?

2. Make a graph to show the formation of an image by a concave lens of 10 cm. focal length of an object 4 cm. high, placed at : (*a*) 20 cm. ; (*b*) 5 cm. from it. Calculate the position of the image by using the general formula.

3. Find the size of the image in the above question : (*a*) by calculation (*b*) graphically.

§ 5. The Convex Mirror

Exp. 1. Arrange a convex mirror, a convex lens, and an object screen, so that the image coincides with the object. Use this combination to determine the focal length of the mirror.

Ques. 1. Make a graph to show the formation of an image by a convex mirror of 6 cm. focal length of an object, 4 cm. high, placed: (*a*) 10 cm., (*b*) 2 cm. in front of the mirror. Calculate the positions of the image.

2. Find the size of the image in the above question: (*a*) by calculation; (*b*) graphically.

3. When a piece of paper is held at a distance of 6″ from a spectacle lens, a small bright image of the sun is formed on it. Where must you hold the paper so that an image of a candle flame, 18″ from the lens, may be formed on it?

4. What is the difference between a real and a virtual image? Illustrate your answer by referring to the images produced by a convex lens.

CHAPTER V

OPTICAL INSTRUMENTS

§ 1. The Astronomical Telescope

Exp. 1. You are provided with a short and a long focus convex lens. Arrange these so as to get a magnified image of a distant object.

Make a drawing to show the course of the rays through the two lenses.

§ 2. The Terrestrial Telescope

Exp. 1. Using an additional short focus lens, obtain a magnified, erect image of a distant object. Make a drawing to show the course of the rays.

§ 3. Galileo's Telescope

Exp. 1. Arrange a convex lens and a concave lens so as to form a telescope. Make a drawing to explain the action.

§ 4. The Compound Microscope

Exp. 1. Arrange a short focus lens to give a real, inverted image of an object. Use a second short focus lens to obtain a magnified image of it. Make a drawing to show the course of the rays.

Ques. 1. In what respect does a terrestrial telescope differ from a microscope, and in what respect are they similar to each other?

2. Explain with reference to a diagram how a concave mirror and a convex lens may be arranged to form a telescope.

3. In what respect does Galileo's telescope prove more useful than the terrestrial telescope? Give reasons for your answer.

4. Describe a camera, and explain its optical effect by means of a diagram.

5. Describe the camera obscura, and explain its action by means of a diagram.

6. Explain with reference to a diagram how a 'magic lantern' throws an image of a lantern slide upon a screen.

CHAPTER VI

DISPERSION

Exp. 1. Place an equilateral prism on a circular disc of cardboard and outline it. Place the disc and prism on paper and draw a circle round the disc. Trace the course of a ray through the prism by means of pins. Mark the position of the disc by setting a mark on the edge of the disc and making a corresponding mark on the paper. Revolve the disc and prism through a small angle and repeat the experiment, until you find the position in which the deviation is a minimum.

Measure the angles of incidence and emergence and show that they are equal. Measure the (minimum) deviation and find the refractive index of the glass of the prism, using the formula :

$$\mu = \sin \tfrac{1}{2}(A + D)/\sin \tfrac{1}{2} A.$$

Exp. 2. You are provided with a screen in which there is a narrow slit, a glass prism, and a convex lens. Arrange the screen and lens so as to get a clear image of the slit on a sheet of cardboard. Now place the prism between the lens and the cardboard and move the latter round, keeping it at the same distance from the prism, until a coloured image of the slit is formed on it. Note the shape and colour of this image. Next move the prism round and find the position in which the deviation is a minimum. Note the appearance of the image in this position. Now cut a broad slit in a piece of cardboard and move it about over the face of the prism and note the change in the image.

Place a second prism near the first one and note the result. Turn the second prism round so that its apex points in the opposite direction to that of the first prism.

Exp. 3. Place a lens in front of the slit so that it forms an image at as great a distance as possible. What will be its distance from the slit? In what way will the light proceed after passing through the lens? Now place the prism in the path of the light and place a second lens on the other side so as to bring the light to a focus on a sheet of cardboard. Describe the appearance of the image, which is known as a pure spectrum.

Ques. 1. What precautions must be taken to obtain a pure spectrum ?

2. Describe and explain the appearance of a window bar, when looked at through a glass prism with its edge parallel to the bar. Make a sketch to illustrate your answer.

3. A horizontal slit in a shutter, through which sunlight is streaming, is viewed through a prism with its base pointing upwards. Will the spectrum seen be a pure one ?

4. A spectrum is seen by looking through a glass prism at a candle flame. Is it a pure one ?

5. A white cross on a sheet of black paper is examined through a magnifying glass. Explain why the image is coloured at its edges, and describe the nature and position of the colours.

Exp. 4.* Describe the experiment in which white light is obtained from a mixture of the colours of the spectrum.

Ques. 1. A piece of blue glass and a piece of red glass are placed together and held up to the light. What colour will be seen through them? Give reasons for your answer.

2. A yellow object is examined in: (*a*) red; (*b*) yellow light. What difference will be noticed, and why?

3. A yellow powder and a blue one are mixed together. Describe the colour of the mixture and account for it.

Note on the Sine of an Angle

Draw an acute angle AOB. Take any point P in one arm. Draw PM perpendicular to the other arm. Measure the lengths of MP and OP and find the value of the ratio MP/OP. Repeat this with the point P in a different position. Use squared paper.

What do you find out about the value of this ratio ?

It is called the *sine of the angle AOB*.

Find the value of the sines of the following angles on squared paper 30°, 45°, 60°.

Construct on squared paper the angle whose sine is : (*a*) $\frac{3}{5}$; (*b*) 0·5 ; (*c*) $\frac{2}{3}$; (*d*) $\frac{3}{4}$.

APPENDIX

I. LIST OF APPARATUS REQUIRED FOR EACH SECTION OR EXPERIMENT

PART II

HEAT

Chapter I

§ 1. (1) Thermometers; (2) glass troughs.

§ 2. (1) Two glass tubes or burettes, funnels, pressure tubing; (2) beakers.

§ 3. (1) Magnesium ribbon; (2) quicklime, basins; (3) sulphuric acid, dry test-tubes; (4) metal buttons; (5) beaker and glass rods; (6) lumps of lead, hammers.

§ 4. (1) Beakers; (2) small test-tubes, wax, lead, sulphur, ferric oxide, mercury oxide; (3) iron wire, retort stands, weights, scales.

Chapter II

§ 1. (1) Retort stand, tripod stand, knitting needles, strips of cardboard; (2) bar and gauge apparatus; (3) ring and ball apparatus; (4) stout copper and iron wire, binding screws.

§ 2. (1) 8 oz. flasks, stoppers, quill tubing, troughs or large beakers; 1 or 2 oz. flasks, quill tubing; (3) special lantern apparatus; (4) beakers, 100 cc. flasks.

§ 3. (1) 4 oz. flask, rubber stopper, narrow glass tube, beakers, eosin solution, strips of cardboard; (2) same as (1) but with a larger flask.

§ 4. (1) Oxygen cylinder; (2) bicycle pump, air thermoscope.

Chapter III

§ 1. (1) Thermometer bulb and tube, small funnel, coloured alcohol.

§ 2. (1) Ice, beakers, and funnels; (2) the same as (1), salt; (3) large flask, rubber stopper, delivery tube bent twice at right angles, salt, sand; (4) flask, &c., as before, gas cylinder, mercury, scale; (5) round bottom flask, stopper, thermometer filled but not graduated.

§ 3. (1) C. and F. thermometers, elastic bands.

§ 4. (1) Maximum thermometer; (2) minimum thermometer, Six's thermometer.

CHAPTER IV

§ 1. (1) Round bottom 8 oz. flask, rubber stopper, short glass tube, rubber tubing, clip, large beakers, ice.

§ 2. (1) Specific gravity bottle or dilatometer, alcohol, &c., large beakers, thread, glass rods.

§ 3. (1) Screw gauges, cover-slips, copper-foil; (2) special apparatus, rubber tubing, tin cans.

§ 4. (1) Floats; (2) coils of compo tubing, corks, narrow glass tubing, strips of cardboard, large beakers, salt or calcium chloride, ice; (3) special apparatus, mercury, freezing mixture; (4) Hope's apparatus.

CHAPTER V

§ 1. (1) Graduated cylinders, scales; (2) beakers, alcohol, &c.; (3) small and large beakers, metals, alcohol, &c.; (4) large and small beakers, metals, test-tubes, cotton wool.

§ 2. (1) Beakers.

CHAPTER VI

§ 2. (1) Steam heaters, calorimeters, outer vessels, cotton wool; (2) calorimeters, &c., beakers; (3) same as (1), metals, &c.; (4) same as (1), liquids.

§ 3. (1) Tin cans, graduated cylinders, lampblack.

CHAPTER VII

§ 1. (1) and (2) Wax, basins; (3) tin cans, wax; (4) glass tubing, beakers, wax, rubber rings, stirring rods; (5) same as (4), butter, sulphur, glycerine.

§ 2. (1) 8 oz. flask, stopper, quill tubing, ice; (2) special apparatus, freezing mixture; (3) tin cans, wax.

§ 3. (1) Tin cans, ice; (2) calorimeters, &c., ice.

§ 4. (1) Beakers, salt, saltpetre, ammonium nitrate, caustic soda; (2) ice, salt, calcium chloride, beakers; (3) salt, ice, tin cans, saucers; (4) sodium thiosulphate, flasks.

§ 5 (1) Large block of ice, copper wire, heavy weight.

CHAPTER VIII

§ 1. (1) Distilling flasks; (2) same as (1), liquids; (3) see Chap. III, § 2, Exp. 4*a*; (4) see Chap. III, § 2, Exp. 4*b*.

§ 2. (1) Tin cans, delivery tubes, calorimeters, &c.

§ 3. (1) Dishes, alcohol; (2) dishes, alcohol, ether, carbon disulphide; (3) barometer tubes, troughs, mercury, filter papers, scales, small funnels; (4) jackets for barometer tubes; (5) special apparatus for boiling-point, a small U-tube containing mercury and the liquid whose boiling-point is to be determined, flasks, stoppers, delivery tubes.

§ 4. (1) Dusters; (2) wooden blocks, watch glasses, ether, bellows; (3) sodium bicarbonate, hydrochloric acid, beakers; (4) cryophorus, freezing mixture.

Chapter IX

§ 1. (1) Flasks, stoppers, delivery tubes, beakers; (2) retorts, flasks; (3) retorts, flasks, mixture of alcohol and water; (4) flask, air-pump.

§ 2. (1) Beakers, ice; (2) clock glasses, caustic soda, calcium chloride, sulphuric acid; (3) aspirator, U-tube, calcium chloride, graduated cylinder, and connecting tubes.

§ 3. (1) Calorimeters, ice; (2) Daniell's or Regnault's hygrometer.

Chapter X

§ 1. (1) Rods of copper and iron, beakers; (2) sensitive paper, copper and iron rods, wooden stands; (3) copper rods and wires, sensitive paper, stands; (4) copper rod, sensitive paper, stands; (5) Edser's or Ingen Hausz' apparatus.

§ 2. (1) Tall beakers, magenta; (2) special apparatus consisting of a glass tube bent in the shape of a rectangle with an opening in the top, magenta; (3) special apparatus consisting of two vessels, a flask and a small bell-jar connected by glass tubes, magenta; (4) paper or cardboard; (5) lamp glass, small glass troughs, candles, cardboard.

§ 3. (1) Test-tubes, sensitive paper, copper wires; (2) test-tubes, copper wires, sensitive paper, mercury, liquids; (3) test-tubes, wax or ice; (4) copper wires, copper rods, glass tubes filled with copper filings, sensitive paper; (5) chalk or sand, copper rods.

§ 4. (1) Cardboard; (2) sensitive paper, hollow tin cubes or cans, Crookes's radiometer, thermopile, and galvanometer; (3) sensitive paper, white lead paint, lampblack, tin-foil, sand-paper; (4) glass plates, tin-foil, paste, sensitive paper or radiometer, &c., metal balls; (5) glass plates, metal balls, sensitive paper, cardboard.

Chapter XI

§ 1. (1) Two glass tubes, one closed at one end and connected to the other by pressure tubing, scales, mercury, small funnels.

§ 2. (1) Quill tubing closed at one end and bent into a U-tube, mercury, tall beaker, scale.

§ 3. (1) Some simple form of air thermometer such as a burette connected by pressure tubing to a T-tube, to the latter is joined an upright tube, and a reservoir to hold mercury. The burette is enclosed in a wider glass tube.

LIGHT

Chapter I

§ 1. (1) Three squares of cardboard; (2) screen with pin-hole, cardboard, candle; (3) and (4) round rulers, screens, scales.

§ 2. Screens, candles, scales.

§ 3. (1), (2), (3), (4) Candles, screens, tissue-paper, scales; (5) unglazed paper.

Chapter II

§ 1. (1), (2), (4), (5), and (6) Plane mirrors (6″ × 1″), stands, pins; (3) retort stand; (7) large mirror; (8) silver coin.

§ 2. (1) and (2) Mirrors, pins.

Chapter III

§ 1. (1), (2), (3), (4), and (6) Rectangular blocks of glass, pins; (5) and (7) glass trough with parallel, thin sides, pins; (8) gas cylinders, glass tubing, cardboard.

§ 2. (1) and (2) Equilateral glass prisms, pins.

§ 3. (1) Right-angled glass prism, pins; (2) rectangular blocks of glass, pins; (3) right-angled prisms; (4) hemispherical glass blocks; (5) beakers or troughs, coins; (6) test-tubes, beakers.

§ 4. (1) Thick sheets of glass, thick glass mirrors.

Chapter IV

§ 1. (1) Concave lenses, pins; (2) convex lenses, pins; (3) concave mirrors, pins; (4) convex mirrors, pins.

§ 2. (1), (2), and (3) Optical benches, concave mirrors; (4) spherometers, cover slips, concave mirrors; (5) scales, concave mirrors.

§ 3. (1), (2), (3), and (5) Optical benches, convex lenses; (4) same as (1), wire gauze.

§ 4. (1) Optical benches, concave and convex lenses.

§ 5. (1) Optical benches, concave mirrors and convex lenses.

Chapter V

§ 1. (1) and (2) Convex lenses, pins.

§ 2. (1) Convex lenses, pins.

§ 3. (1) Concave and convex lenses, pins.

§ 4. (1) Convex lenses, pins.

Chapter VI

§ 1. (1) Circular discs of cardboard, equilateral glass prisms, pins; (2) and (3) screens, equilateral glass prisms, convex lenses; (4) Newton's disc, whirling table.

II. NOTES ON THE EXPERIMENTS

PART II

HEAT

Chap.	§	*Exp.*	
II	2	3	The apparatus consists of three small thermometers, filled with mercury, water, and alcohol, respectively. They are fixed to a stand with a transparent scale, and the bulbs are fixed in a small trough.
II	2	4	The class may be divided.
III	2	4	The delivery tube from the flask dips into a cylinder, in which mercury is poured. In the second experiment a small beaker of warm water is placed under the receiver of the air-pump.
III	2	5	Thermometers filled with mercury and sealed but not graduated may be obtained.
IV	1	1	A test-tube fitted with a cork and glass tube drawn out into a capillary may be used and the water may be weighed.
IV	2	1	Dilatometers of small capacity and readily filled without heating and cooling may be obtained. Mercury can then be used.
IV	3	2	The cheapest form of apparatus for this purpose can be made by having a number of metal tubes with flat ends and side tubes to admit the steam and allow it to escape, and a single gauge made of a metal rod bent over at one end so as to press against one end of the tube and fitted with a screw gauge at the other.
V	1	2	Divide the class so that each boy takes two lots only.
V	1	3, 4	It is understood that the heat-capacities of equal masses is compared.
V	2	1	Each experiment is to be performed in two ways.
VI	2	1	A convenient steam heater consists of a zinc can with a handle. In the top there is an opening, in which a cork is placed, carrying a long bent glass tube, and another opening which forms an inner compartment, in which the substance is placed.
VII	2	1	A burette containing oil at 0° C. may be used. The ice is dropped into the oil and the volume determined; it is then allowed to melt.
VII	5		The experiment in which a block of ice is apparently cut in two may be done.
VIII	1	3	See Chap. III, § 2, Exp. 4*a*.
VIII	1	4	See Chap. III, § 2, Exp. 4*b*.
VIII	3	1	It is better to use alcohol. Graphs may be constructed.
VIII	2	3	The same barometer tube may be used.
VIII	3	5	A U-tube with a short limb drawn out into a capillary is filled with mercury, and the given liquid is passed into the short limb, which is then sealed off. The mercury in the longer limb must be at the lower level.

HEAT (*continued*)

Chap.	§	*Exp.*	
X	1	2	The sensitive paper may be obtained from W. B. Nicholson, 54 Hill Street, Garnet Hill, Glasgow. It is placed on a flat board and the rods are laid upon it. One end of the rod is bent down and dips into a crucible containing mercury, which is heated. The edge of the stand is turned up to shield the paper from the heated mercury.
X	3	4	The ends of the copper rod and tube rest on the sensitive paper.
X	4	2	The rate at which the vanes revolve may be taken as a measure of the radiation.
X	4	3	Use lampblack, tin-foil, &c.
X	4	4	Tin-foil on glass or tin-plate may be used.
X	4	5	Stripped negatives may be used.

LIGHT

I	3	1	The optical bench may be used.
II	1	1	The mirrors may be supported in slits in a wooden block or a cork.
IV	1	1	If the distances at which the object pin is to be placed are given, much time will be saved.
IV	2	1	A simple optical bench may be made out of a drawing board, a scale, and a sheet of paper. Spectacle lenses of not too long a focal length may be used. Pin methods may be used entirely. In this case lenses which have been cut in two should be used.
V	1, &c.		The position of the image formed by the object lens should be found with a pin by the parallax method.
VI	1	1	The position of minimum deviation may also be found by placing one of the pins against the side of the prism at a marked point and revolving it, taking care that the pin always touches the side at the same point.

III. LIST OF APPARATUS

HEAT

†Apparatus:
- Bar and gauge.
- Compound bar.
- Ring and ball.
- Expansion of liquids (for lantern).
- Expansion of a solid.
- Maximum density (lantern).
- Expansion of water on freezing.
- Convection current.
- Circulation of water.
- Constant volume air-thermometer.
- Edser's conductivity.
- Ingen Hausz'.
- Hope's.
- Daniell's hygrometer.
- Regnault's „

Aspirator.
Beakers, litre.
Buttons, metal.
†Barometer tube.
Burners.
Binding screws.
†Bellows.
†Compo tubing.
Candles.
†Cryophorus.
Cover slips.
Cotton wool.
Calorimeters and outer vessels.
Dilatometers.
Drawing boards.
Floats, metal or glass.
Flasks, distilling.
Glass beads.
Glass plates.
Indiarubber pressure tubing.
Jackets for barometer tubes.
Lampblack.
†Mercury trough.
Needles, knitting.
Nails, copper, iron, brass.
†Oxygen cylinder.
†Pump, cycle.
Rods of copper, steel, and glass.
Retorts, glass.
†Radiometer, Crookes's.
Sensitive paper.
Stands, wood, for conduction experiment.
Screw gauges.
Steam heaters.
Tubing, thermometer.
Thermoscope, air.
Thermometer tubes and bulbs.
„ „ „ „ filled.
„ weight.
† „ maximum.
† „ minimum.
† „ clinical.
† „ Six's.
Troughs, glass.
†Thermopile and galvanometer.
White lead paint.

LIGHT

Glass, rectangular blocks; equilateral prisms; right-angled prisms; plates, thin.
Gauze, wire.
Lenses, concave and convex.
Mirrors, plane; thick glass; concave and convex.
†Newton's disc.
Optical benches.
Pins, bonnet.
Paper, tissue.
Spherometers.
Wooden rulers, black.
†Whirling table.

† Of apparatus marked with a dagger (†) only one piece is necessary

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